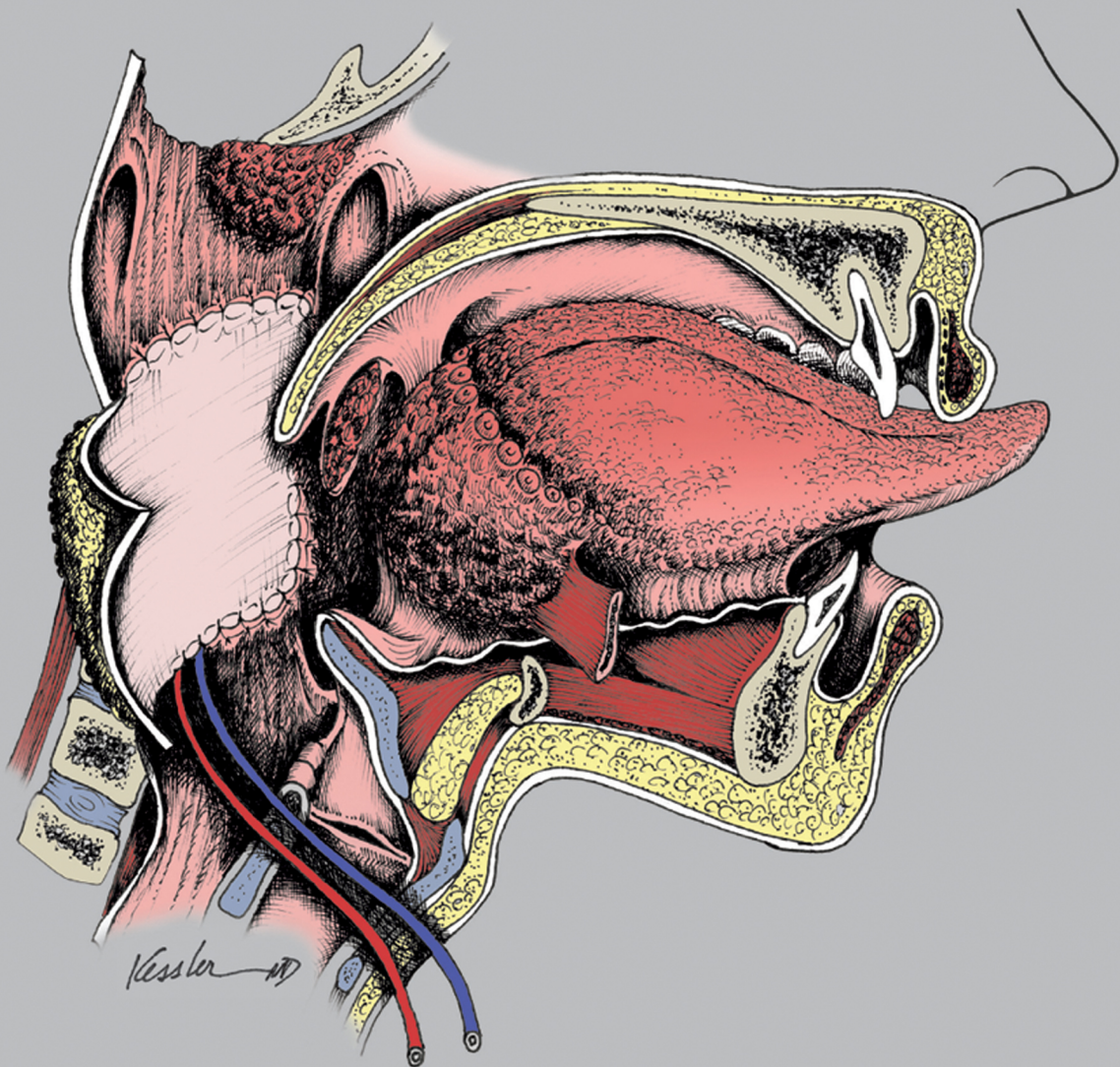


Reconstruction of the Head and Neck

A Defect-Oriented Approach

Eric M. Genden



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A Defect-Oriented Approach

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I dedicate this book to my patients and their families. It is my hope and expectation that this book will assist surgeons and surgeons in training to restore their patients to enjoy the quality of life they deserve. I also dedicate this book to my wife, Audrey, and my children, Eric Jr., Sophia, and Isabelle, for their support and love.

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Foreword

The evolution over the past four decades of head and neck reconstructive surgery began with a revolution in flap surgery. Any surgeons who had witnessed the plight of patients with large and complex defects of the head and neck before the “modern era” would agree that there was a need for change. There may, however, be some disagreement over the exact advent of the “modern era” of head and neck reconstruction. A few might feel that it began when Seidenberg reconstructed a total laryngopharyngectomy defect with a vascularized jejunal segment in 1959. That was indeed a milestone, but failed to translate into wide application for many years, even for this specific defect. Some would credit McGregor in 1963 and Bakamjian in 1965 with ushering in the modern era with the introduction of the first reliable axial pattern skin flaps from the forehead and shoulder respectively. These flaps were indeed used extensively by head and neck surgeons in the 1960s and 1970s for a wide variety of defects, but usually failed to duplicate the missing tissue.

Others would cite Buncke’s microvascular transfer of omentum to cover a large full thickness scalp defect in 1972. Most historians would mention Taylor and Daniels. In 1973, their transfer of a microvascular free cutaneous groin flap to the sacral area was a watershed event in reconstructive surgery. The first application of a free cutaneous flap to the head and neck occurred in 1975 when Panje et al used a free groin flap for tongue reconstruction. Few would disagree that the predictable and reliable reconstruction of the mandible began in 1978 when Taylor demonstrated that the original free cutaneous flap—the groin flap—was incapable of successfully carrying iliac bone on its superficial circumflex iliac arterial pedicle. Instead he showed that the deep circumflex iliac arterial pedicle supplied the iliac crest and would carry the overlying skin in a predictable fashion. At that time, very few head and neck surgeons were performing microvascular free flaps, and the introduction of the pedicled pectoralis major flap a year later in 1979 did little to swell the ranks of free flap surgery advocates.

As both a spectator and a participant in this change, I believe that the modern era could not be declared before the

majority of the head and neck surgeons were critically employing the wide spectrum of available modern surgical options. As such, I see this modern revolution in head and neck reconstructive surgery as akin to any social revolution. First, there is the idea and innovation phase. This is where the aforementioned authors and their contributions fall. There follows a debate phase, during which the original ideas are expanded and new ideas added. During the 1980s, a flood of new flaps were introduced. Every revolution has a phase of conflict. The 1980s and the early 1990s were a contentious period, when many surgeons clung tenaciously to specific flaps or reconstructive techniques often at the expense of progress. For years, the head and neck surgical community was split between the practitioners who utilized all available flaps but usually favored free tissue transfer and those who used pedicled musculocutaneous flaps for every reconstruction. All revolutions have a resolution when the phase of conflict winnows out the ideas that have the most traction. By the early 1990s, this had happened with head and neck reconstruction. Free tissue transfer offered the closest match of donor tissues with those missing in the head and neck defect. Consensus was established on a relatively small number of flaps and grafts. Then the inevitable overshoot happened, as happens in all revolutions. By 2000, we started to see, in some centers, complex microvascular free tissue transfer being employed to reconstruct small defects that could have been equally or in some cases even better repaired with simple local or regional flaps or even, in rare cases, healing by secondary intention.

I am honored to write this foreword for *Reconstruction of the Head and Neck: A Defect-Oriented Approach*. Professor Eric M. Genden ranks as one of today’s foremost head and neck surgeons. Not only is he accomplished in conventional diagnostic and ablative techniques in the head and neck but he is also on the cutting edge of new and developing surgical strategies, such as transoral and robotic surgery. As a role model for the modern head and neck surgeon, Dr. Genden is equally facile as a reconstructive surgeon. He is accomplished in today’s conventional reconstructive techniques, microvascular free tissue transfer, and the still important

Foreword

local and regional flaps, while being an innovator exploring new strategies for reconstruction, such as transplantation and tissue engineering for tracheal replacement. Above all, he is a superb educator. This book is abundant evidence of his dedication to teaching. It is a superb addition to the literature and very timely. The current frontline techniques for dealing with defects of the head and neck are presented in a clear, concise and well-organized fashion. The reader is prompted to approach the repair of each defect with a graduated mindset from simple to complex. This book can serve

as a reference for the resident and the practitioner, for every surgeon who wants to perform head and neck surgery. Dr. Genden makes a great contribution to head and neck reconstructive surgery with this book.

Richard E. Hayden, MD
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Preface

Reconstruction of the head and neck requires a profound understanding of the anatomy, physiology, and function of the upper aerodigestive system. The relationship between form and function makes reconstruction of the head and neck a unique challenge. This book is written as a defect-oriented guide to reconstruction. Each chapter is devoted to a region of the head and neck. The chapters are further organized by specific defect, so that the reader can identify a defect and explore the reconstructive options. The approaches to reconstruction are covered in detail and are

designed to review the fine points that are often not addressed in general reconstructive texts. The order of events, the orientations of the flap, and the details that confer excellent functional and aesthetic results are covered in each section for each defect.

Achieving optimal results in head and neck reconstruction requires attention to function and form. We hope this book will serve as a guide for the reconstructive surgeon and provide the finer points essential to achieving excellent long-term results.

Biographies



Eric M. Genden, MD, is a graduate of Columbia University and the Mount Sinai School of Medicine, New York, New York, where he completed his degree with a distinction in Research. He then completed residency training in otolaryngology–head and neck surgery at Washington University, Barnes Hospital St. Louis, Missouri, and then completed fellowship training in head and neck oncology and microvascular surgery at The Mount Sinai Medical Center, New York, New York.

Dr. Genden is nationally recognized as one of the country's top head and neck cancer surgeons and is regularly listed as one of America's Top Head and Neck Surgeons and America's Leading Cancer Surgeons. His expertise in management of oral cancer and microvascular reconstruction of the head and neck has contributed to the national reputation for excellence at Mount Sinai Hospital. Dr. Genden has published more than 150 manuscripts and chapters and is the author/editor of this book and two others: *Head and Neck Cancer: A Multidisciplinary Approach* and *Free Flap Surgery*.



Scott M. Kessler, MD, is a Board Certified Otolaryngologist in private solo practice in New York, New York. He has been on the Attending Staff at Mount Sinai Medical Center, New York, for the past 28 years. He earned his medical degree at the Mount Sinai School of Medicine, and following a surgical internship at the Barnes Hospital in St. Louis, Missouri, he completed his residency in Otolaryngology at Mount Sinai Hospital in New York. He specializes in Care of the Professional Voice, and his patients include a wide diversity of performing artists from all aspects of theater, broadcasting, and the entertainment recording industry. He has lectured locally and internationally, and has been featured in journals, on radio and television, and in several documentary films as a prominent expert in the field of Performing Arts Medicine.

Dr. Kessler's interest in medical illustration began in medical school, where he drew for his professors and research fellows for journals. During his residency, his illustrations were published in hundreds of articles, and since then his work has appeared in textbooks, monographs, and journals. In addition to his detailed pen-and-ink drawings, he also enjoys painting large abstract-expressionist canvases and oversize botanical acrylics.

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Oral Cavity Reconstruction

Eric M. Genden, William Lawson, Andrew Sikora, Andrew Kleinberger, Vijay Mukhija, and Mark K. Wax

In most situations, surgery is the first-line management of oral cavity carcinoma. Thus it is vitally important to consider the impact of surgery and reconstruction on articulation and swallowing. Although the oral tongue is important in the articulation of speech and the oral phase of swallowing, the base of the tongue is important in airway protection and the pharyngeal phase of swallowing. Surgery of the oral cavity often compromises sensation and dynamic motion of the tongue, so reconstructive techniques that result in tethering of the oral tongue nearly always lead to impaired function. Such impairment was common in the 1970s, when tongue flaps and skin grafts were the mainstay of oral cavity reconstruction. In the 1980s, pedicled regional flaps such as the pectoralis and latissimus myocutaneous flaps were introduced. Although these flaps provided an excellent source of tissue for head and neck reconstruction, the pedicled nature of these flaps often resulted in pulling and tethering during the course of healing. This led to impaired movement of the remaining muscular tongue, which in turn translated into poor functional outcomes.

The major advantage of free tissue transfer for oral cavity reconstruction is the ability to use pliable soft tissue that contours to the complex anatomy of the oral cavity and moves with the residual muscular tongue. Donor sites such as the radial forearm and anterolateral thigh provide the unique potential for sensory reinnervation.^{1,2} Although sensory reinnervation has been cited as an advantage for oral cavity reconstruction, the data are less convincing. Restoring the complex anatomy and function of the oral cavity following tumor ablation is a challenge. A thoughtful approach to flap design and an appreciation of the neuromuscular and sensory anatomy are vital to ensure a successful final result.

◆ RELEVANT ANATOMY

The complexity of speech and swallowing is reflected in the complex neurosensory and neuromuscular anatomy of the oral cavity. The oral cavity is defined as the region extending

from the lips to the junction of the hard and soft palate above and to the line of the circumvallate papillae below. The area includes the lips, the buccal mucosa, the upper and lower alveolar ridges, the retromolar trigone, the anterior two thirds of the tongue (oral tongue), the floor of the mouth, and the hard palate. The complex anatomy of the oral cavity includes muscle, nerve, salivary glands, and mucosa. Sensation of the buccal mucosa is provided by the second and third branches of the trigeminal nerve. The buccinator muscle is innervated by the facial nerve.

The anterior aspect of the oral tongue is part of the oral cavity, whereas the posterior third of the tongue is part of the oropharynx. The muscles of the tongue include the hyoglossus, styloglossus, and genioglossus. Working with the extrinsic muscles of the tongue, the intrinsic tongue musculature is essential for articulation and swallowing. The styloglossus acts to draw the tongue posterior during swallowing, whereas the hyoglossus flattens the tongue by drawing it toward the hyoid. Both movements are an important aspect of speech and swallowing. The hypoglossal nerve is responsible for motor innervation of the tongue, and the lingual nerve provides sensation for the oral tongue.

The floor of the mouth is the area between the mandibular alveolus and the oral tongue. It extends posterior to the anterior tonsillar pillar. The area of the floor of the mouth is composed of a sulcus of mucosa that provides the freedom of the tongue to move without restriction. There are also several important structures in the region including the submandibular duct orifice, the submandibular duct, and the lingual nerve.

◆ EVALUATION OF THE ORAL CAVITY DEFECT AND BIOMECHANICAL CONSIDERATIONS

The goals of oral cavity reconstruction are to preserve the movement of the remaining native oral tongue, provide the appropriate bulk to optimize speech and swallowing,

maintain velopharyngeal competence, and preserve sensation. As discussed earlier, the dynamic tongue motion is essential to preserve speech and swallowing. Following tumor ablation, the remaining functional tongue must be free to move untethered, to preserve articulation of speech and swallowing. Equally important is maintaining the bulk of the flap. This is important in preserving the tongue-to-palate contact that is essential for articulation. Finally, velopharyngeal closure and sensation are important in both swallowing and speech. If not properly addressed, a soft palate resection can result in either velopharyngeal stenosis or velopharyngeal insufficiency. Reconstruction of the muscular velopharyngeal sphincter should be a priority when the soft palate is involved in the ablative resection. Simply relining the area with a soft tissue flap does not provide the appropriate dynamic closure that is essential for an optimal functional result.

Equally important is the role of sensation in swallowing. Although the data related to flap reinnervation are equivocal, maintaining oral mucosa sensation can be very helpful in manipulation of the food bolus.^{2,3}

◆ CLASSIFICATION OF ORAL CAVITY DEFECTS

There is no universally accepted classification scheme for oral cavity defects, largely because there are innumerable potential combinations of defects. Generally, defects of the oral cavity can be classified into the following schema:

1. Hemi-oral glossectomy ($\pm$ floor of mouth; $\pm$ mandible)
2. Total oral glossectomy ($\pm$ floor of mouth; $\pm$ mandible)
3. Buccal defect ($\pm$ floor of mouth; $\pm$ mandible)
4. Partial soft palatal defect
5. Total soft palatal defect

The $\pm$ sign means that the glossectomy defects are designated as associated or unassociated with a floor-of-mouth or mandibular defect, because when the floor of mouth or the mandible are involved, special attention should be directed to the design of the flap to prevent tethering of the oral tongue and to take into account the bony defect. The same concept holds true for buccal defects. The soft palate defects are divided into partial and total defects because in most cases the former allows for restoration of the velopharyngeal muscular sphincter whereas the latter assumes that the muscular sphincter cannot be restored. Although this classification system is simplistic, the components of the system are designed to address the important functional considerations and serve as a guide for reconstruction.^{4,5}

◆ THE ORAL CAVITY DEFECT

The Floor of Mouth

Choosing the appropriate method of reconstruction of the floor of mouth can have a significant impact on oral dental rehabilitation. As discussed earlier, the most important tenet of oral cavity reconstruction is that the tongue must not be

restricted or tethered. Although skin grafts, local flaps, and free flaps all represent options for reconstruction, choosing the optimal donor site depends on the extent of the defect and the location of the defect. Small to medium-sized defects of the alveolus and floor of mouth can be managed with a buccal flap, a skin graft, or a free flap. However, defects of the floor of mouth that encroach on the tongue often require free tissue transfer because skin grafts tend to contract, thereby restricting the tongue. Similarly, buccal flaps tend to pull the tongue laterally. Other factors that should be considered are the patient's goals for oral dental rehabilitation. In those patients who desire osseointegrated implants, the soft tissue reconstruction should be low profile with as little bulk as possible. Thin low-profile tissue allows for better denture retention. Bulky flaps hinder retention of a tissue-borne denture and often require revision.

Option for Management: Split-Thickness Skin Graft

The split-thickness skin graft provides an excellent source of thin tissue for floor-of-mouth reconstruction. The split-thickness skin graft is best suited for small to medium-sized defects in which the soft tissue bed is well vascularized and it facilitates graft healing. Because the graft is thin, implant-borne and non-implant-borne dentures can be retained quite well and often do not require revision surgery.

Surgical Technique and Considerations (Fig. 1.1)

- ◆ The split-thickness skin graft should be harvested at approximately 0.17-mm thickness. The graft should be harvested only slightly larger than the defect so that there is minimal redundancy yet it can accommodate contracture.
- ◆ The graft should be trimmed to the size of the defect and then sutured into position with an absorbable suture.
- ◆ After the graft has been sutured into place, a bolster of petroleum-impregnated gauze should be constructed and sutured to secure the skin graft.



Fig. 1.1 Clinical case. The split-thickness skin graft provides a low-profile reconstructive technique that accommodates either osseointegrated implants (seen here) or a tissue-borne denture.



Fig. 1.2 Clinical case. **(A)** For the alveolar and floor of mouth defect, the facial artery mucosal muscular (FAMM) flap is designed by using a Doppler to identify the arterial pedicle (arrows). **(B)** The flap is designed to the appropriate length to provide oral cavity lining. **(C)** The flap is transferred into the defect and sutured with absorbable suture.

Patient Selection and Perioperative Management

The split-thickness skin graft should be used in patients with small to medium-sized defects that do not involve the tongue or ventral surface of the tongue. These areas tend to contract and restrict the tongue motion. The grafts should be used with caution in those patients who have been previously treated with radiotherapy because the grafts have a higher rate of sloughing. Split-thickness grafts often heal well over alveolar bone if the bone is well vascularized and the periosteum is intact. In those cases where the periosteum has been removed, the cortical bone can be drilled down to expose bleeding bone.

Postoperatively, we recommend the bolster be kept in place for 5 days. During that time, the patient remains on antibiotic therapy and is placed on a full liquid diet. Dentures are not fabricated for 6 weeks to allow for complete healing.

Option for Management: Facial Artery Mucosal Muscular Flap

The facial artery mucosal muscular (FAMM) flap is a vascularized pedicled flap based on a branch of the facial artery. The flap can be pedicled superior or inferior depending on the defect location. For most floor of mouth, alveolus, and lateral tongue defects, the inferior-based FAMM flap is appropriate.⁶ Because the FAMM flap is a pedicled flap, it is well vascularized and is ideal for inferior-located oral cavity defects, even in the setting of prior radiation.

Surgical Technique and Considerations

- Once the resection is complete, the FAMM flap is designed to the specifications of the defect. Although redundancy is not necessary, it is important to design the flap with enough length to accommodate rotation of the flap without tension (**Fig. 1.2A**).

- The flap can be designed to be pedicled inferiorly for floor-of-mouth and alveolar defects.
- The vascular pedicle can be localized using a Doppler.
- The parotid duct should be cannulated prior to the flap harvest to prevent injury to the duct.
- The flap is then harvested and rotated into the defect. Absorbable sutures can be used to achieve the closure of the donor site and the recipient site (**Fig. 1.2B**).
- Several weeks after surgery, the healing is complete. The flap heals flush with the alveolus and floor of mouth, assuming the natural contour of the oral cavity (**Fig. 1.2C**).

Patient Selection and Perioperative Management

Postoperatively, the patient should be NPO (nothing by mouth) for 4 to 5 days to promote healing. Dental rehabilitation should not begin before 6 weeks following surgery.

Patients with alveolar defects and minimal floor-of-mouth defects are ideal candidates for the FAMM flap. This is a reliable and well-vascularized flap that heals and adapts well to the floor-of-mouth mucosa. In some cases, the pedicle of the flap may contract, causing tension or mild trismus. This can be managed by lysis of the pedicle 6 to 8 weeks after the initial surgery.

Option for Management: Radial Forearm Free Flap

Larger defects of the floor of mouth often require free tissue transfer. The thin pliable tissue of the radial forearm free flap⁷ is ideal for floor-of-mouth reconstruction. The tissue contracts minimally and in most cases is thin enough to accommodate dentures with minimal revision or tissue thinning.

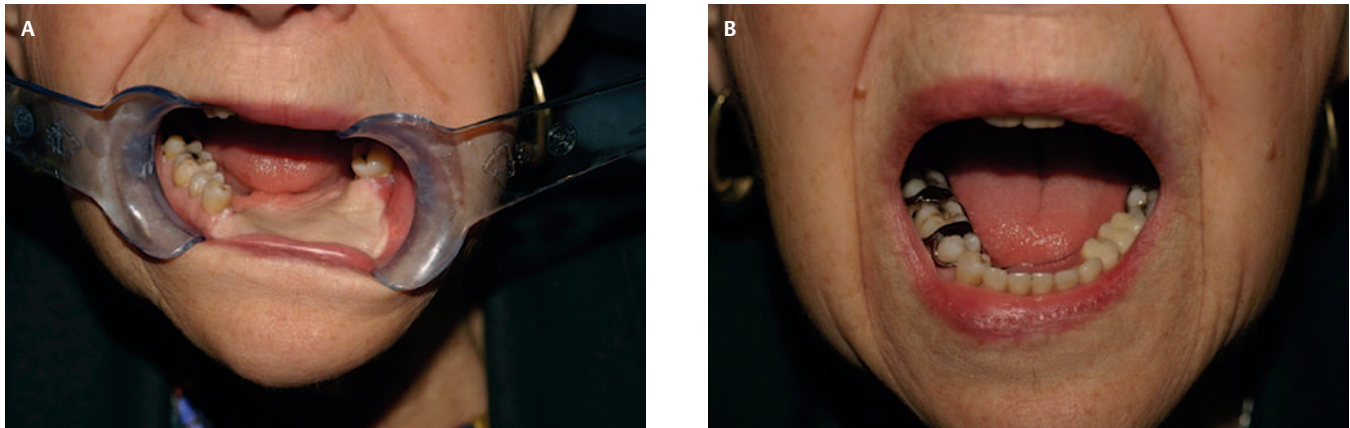


Fig. 1.3 Clinical Case. **(A)** Larger defects that communicate with the neck can be managed with a radial forearm free flap. The skin paddle contours to the alveolus and floor-of-mouth anatomy. **(B)** The thin, low-profile skin paddle can accommodate a tissue-borne denture.

Surgical Technique and Considerations

- ◆ The radial forearm flap can be designed to the exact dimensions of the floor-of-mouth defect (**Fig. 1.3**).
- ◆ The flap can be sutured into the floor-of-mouth defect with absorbable suture.
- ◆ No bolster is necessary.
- ◆ The vascular pedicle can be drawn through a floor-of-mouth defect to align the vascular pedicle with a donor vessel for the microvascular anastomosis.

Patient Selection and Perioperative Management

Patients with larger defects of complex wounds that have been exposed to radiotherapy are ideal candidates for the radial forearm reconstruction. Patients with defects that extend onto the ventral surface of the tongue or lateral tongue are also best suited for this reconstruction. Modifications of this flap, such as inclusion of subcutaneous adipofascial tissue in the distal part of the flap to fill dead space under the floor of mouth,⁸ or use of a bilobed flap for defects involving the floor of mouth and tongue,⁹ have been described.

Postoperatively, we recommend that the patient be NPO for 5 to 7 days to facilitate healing. Dental restoration should not begin before 8 to 12 weeks when the flap has healed to the deep tissue.

◆ THE PARTIAL GLOSSECTOMY DEFECT

The partial glossectomy defect can range from a small superficial resection of the lateral tongue to a hemiglossectomy defect. Depending on the size, defects that involve the oral tongue can be managed with a variety of reconstructive options including primary closure, healing by secondary intention, a split-thickness skin graft, a local flap, or a free flap. However, when the floor of mouth is involved in addition to the oral tongue, healing by secondary intention and

split-thickness skin graft techniques are less desirable because of the inevitable scar contracture that ensues. Primary closure is not usually an option, and therefore free tissue transfer is typically the primary reconstructive option. Select defects can be managed with regional flaps like the submental island flap¹⁰; however, one must consider the potential risk of transferring a submental metastasis into the donor site.

Option for Management: Primary Closure

In select patients, small defects of the oral tongue can be closed primarily. It is always difficult to exactly determine the threshold for when a defect is best managed with primary closure versus a skin graft versus a free flap. The decision is often based on a combination of experience and instinct. Unlike a skin graft or a free flap, the primary closure technique preserves sensate mucosa, which is helpful in oral rehabilitation (**Fig. 1.4**).

Generally, we suggest that if primary closure appears to tether the tongue from freely moving from side to side, another option should be considered.

Option for Management: Radial Forearm Free Flap

The radial forearm remains the optimal donor site for oral tongue reconstruction due to its versatility and often excellent functional results.¹¹ The thin pliable tissue allows for contouring to the oral tongue and the floor of mouth in a way that cannot be achieved with other soft tissue donor sites. Other advantages include the ability to reinnervate the flap to provide sensation.^{1,12} Some clinicians have criticized this donor site because the thin tissue characteristic of the volar surface of the forearm may be inadequate to provide the bulk necessary to fill a hemiglossectomy defect; however, fat can be harvested from the forearm to adequately provide bulk to the flap.

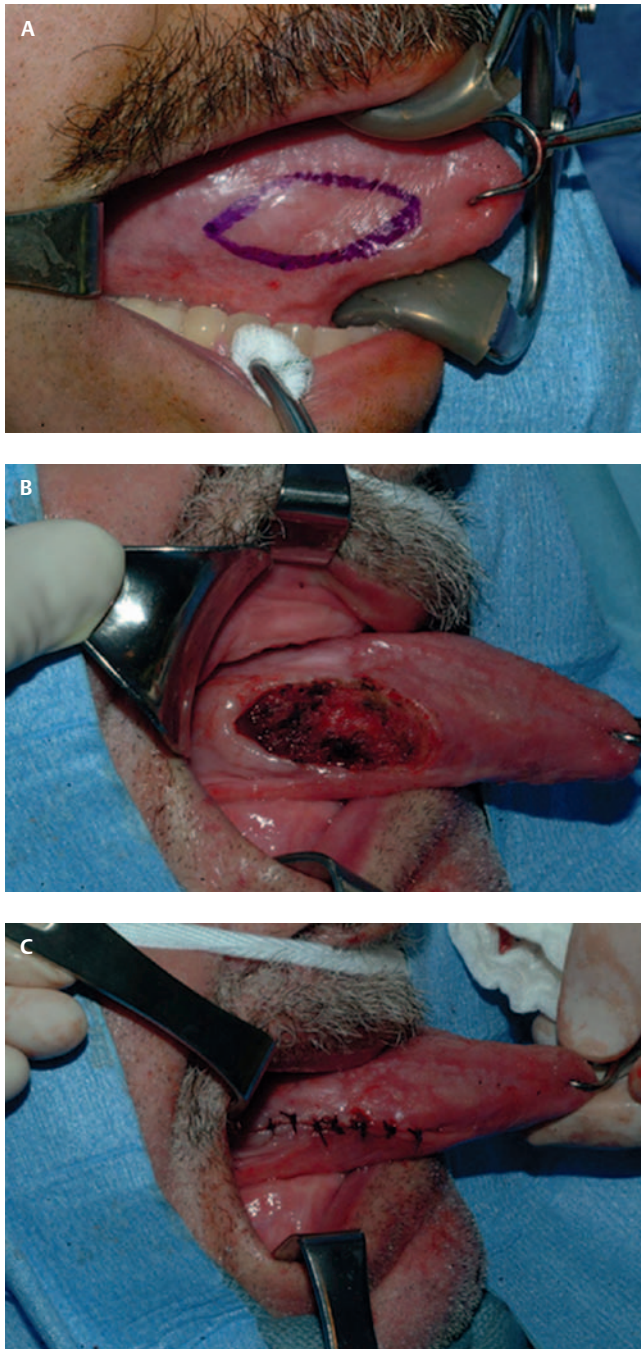


Fig. 1.4 (A) Clinical case. A superficial oral tongue cancer. (B,C) A superficial oral tongue defect without involvement of the floor of mouth is amenable to primary closure.

Surgical Technique and Considerations

- ◆ After clear margins have been established, the design of the flap is predicated on the necessity for floor-of-mouth lining and bulk. In most cases, the oral tongue can be reconstructed transorally without the need for a midline mandibulotomy (**Fig. 1.5**). In some cases, a “pull-through” technique¹³ may facilitate the resection and the reconstruction (**Fig. 1.6**).



Fig. 1.5 Most anterior oral cavity defects can be reconstructed through a transoral approach.



Fig. 1.6 Tumors that extend posteriorly may require a midline mandibulotomy or a “pull-through” approach (seen here). The pull-through approach provides excellent exposure.

Reconstruction of the Head and Neck

- ◆ If floor-of-mouth lining is required, the flap can be designed using a bilobed skin paddle to accommodate the oral tongue defect and the floor-of-mouth lining without tethering the tongue (**Fig. 1.7A**).
- ◆ If the floor of mouth is not involved, the flap can simply be designed to accommodate the oral tongue defect. The bilobed flap can be harvested with fat along the vascular pedicle to protect the vessels from thrombosis in cases where there is a high risk of salivary leak (**Fig. 1.7B**).
- ◆ When bulk is required, vascularized fat can be harvested along the proximal aspect of the flap (**Fig. 1.8A**).
- ◆ The flap can then be designed such that the vascularized fat is rolled under the skin paddle (**Fig. 1.8B**).
- ◆ This provides the increased flap volume that is important for preservation of speech (**Figs. 1.8C,D** and **1.9**).

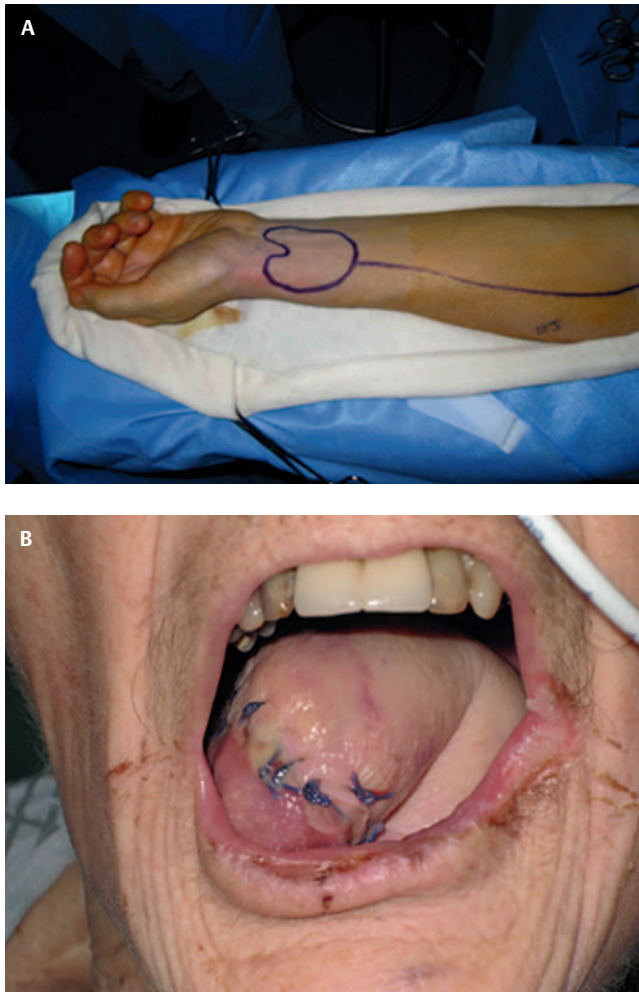


Fig. 1.7 (A) The bilobed radial forearm flap design provides a lobe skin paddle for the oral tongue and a second lobe skin paddle for the floor of mouth lining. This design preserves the tongue mobility. (B) One week postoperatively, the bilobed design provides tongue mobility that is important for articulation and swallowing.

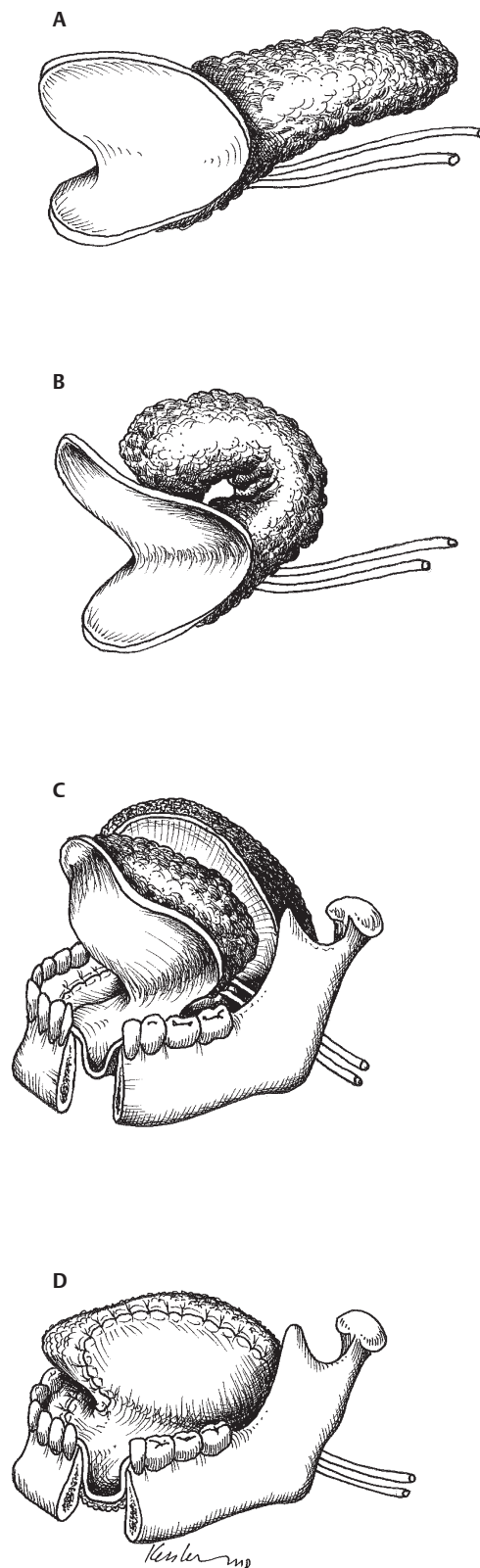


Fig. 1.8 (A) A vascularized fat graft can be harvested with the radial forearm flap skin paddle. (B) The fat graft can be rolled under the skin paddle to increase bulk and volume of the reconstruction. (C) The fat graft and the skin paddle are used to maintain the oral tongue volume. (D) The completed reconstruction preserves the tongue mobility and oral volume essential to speech and swallowing.

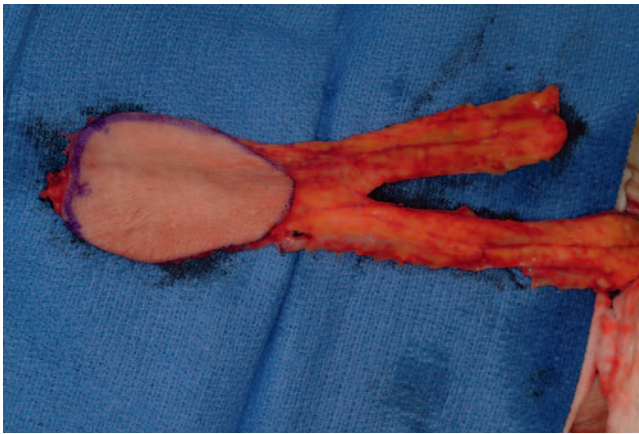


Fig. 1.9 Clinical example of the radial forearm flap and vascularized fat graft used to add volume to the radial forearm skin paddle.

- ◆ The flap should be designed to accommodate the defect with marginal redundancy.
- ◆ The vascular pedicle should be drawn into the neck medial to the mandible to eliminate compression of the pedicle.
- ◆ After the tongue defect has been reconstructed, the microvascular anastomosis can be performed.
- ◆ When choosing a donor vessel, kinking should be minimized. The transverse cervical vessels provide excellent geometry for flaps with a longer vascular pedicle.

Patient Selection and Perioperative Management

Superficial defects of the tongue heal well either with a split-thickness skin graft or by secondary intention. More substantial defects often require free tissue transfer. In most patients, the radial forearm provides an excellent source of tissue; however, in thin patients, either a vascularized fat flap or an alternative donor site, such as the anterolateral thigh or lateral arm, may provide the bulk necessary to optimize function. In those patients who sustain sacrifice of the lingual nerve, reinnervation of the flap can be beneficial to long-term function. Establishing the appropriate bulk is important to optimize articulation.

Postoperatively, patients remain NPO for 5 to 7 days depending on their nutritional status and prior radiation history. For those with poor nutritional status, or who have been treated with external beam radiotherapy, we prefer to delay oral feeding for 10 to 14 days.

Option for Management: Lateral Arm Flap

When the oral tongue defect extends posteriorly to involve a portion of the base of tongue, a thin anterior flap with bulk in the posterior aspect of the reconstruction may be desirable. The lateral arm flap¹⁴ has the advantage of providing minimal thickness in the distal flap and more bulk proximally. This unique characteristic provides the opportunity

to restore the anterior tongue with the distal portion of the flap, and the base of tongue with the proximal aspect of the flap.

Surgical Technique and Considerations

- ◆ Once the tumor margins have been established, the flap can be designed. The thin tissue located in the distal aspect of the flap will be oriented anteriorly, whereas the proximal, more bulky tissue will be oriented to the posterior defect, where bulk is desirable.
- ◆ Because the lateral arm vascular pedicle is shorter than the radial forearm flap, the vascular pedicle can be oriented to the facial or superior thyroid vessels.
- ◆ The lateral arm flap also has the advantage of sensory reinnervation, and, if indicated, the flap can be innervated via the lingual nerve.

Patient Selection and Perioperative Management

This donor site is ideal for defects involving the oral tongue and a portion of the base of tongue. Because the vascular pedicle is shorter than that of the anterolateral thigh and radial forearm flaps, this donor site can be a challenge in patients with a vessel-depleted neck.

Postoperatively, patients remain NPO for 5 to 7 days depending on their nutritional status and prior radiation history. For those with poor nutritional status or who have been treated with external beam radiotherapy, we prefer to delay oral feeding for 10 to 14 days.

◆ THE TOTAL ORAL GLOSSECTOMY DEFECT

The total oral glossectomy defect can be managed using a variety of donor sites, such as the anterolateral thigh flap, the radial forearm flap, or the lateral arm flap. Each has advantages and disadvantages. Other reconstructive options have been described including the submental island flap and the pectoralis flap. Regardless of the donor site choice, functional success is largely dependent on the ability to preserve base-of-tongue mobility and oral neotongue bulk. The integrity of the hypoglossal nerve and base-of-tongue innervation is essential to provide airway protection and preserve the oropharyngeal phase of swallowing. When movement of the base of tongue is compromised, the risk of aspiration rises. Similarly important is the neotongue bulk, which is essential to preserve speech and articulation. Planning the reconstruction such that the oral neotongue maintains bulk is important for long-term function. When the base-of-tongue movement is preserved and the oral tongue bulk is established, the functional results of a total oral tongue reconstruction can be exceptional. In contrast, when the reconstructed tongue is unable to contact the hard/soft palate complex, articulation and speech intelligibility can be severely compromised. In those cases where the bulk

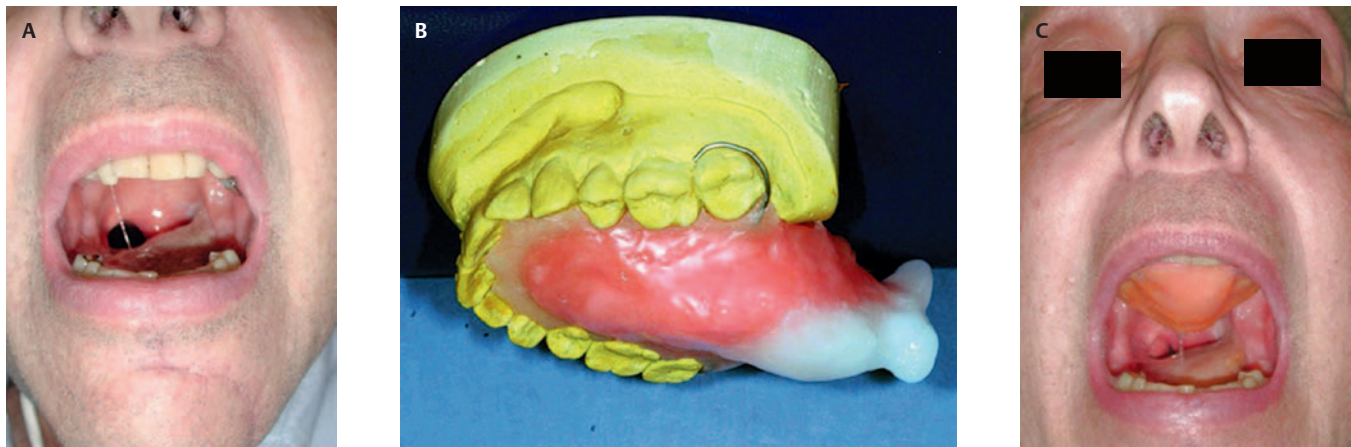


Fig. 1.10 (A) A deficiency in the oral tongue reconstruction will impair speech and swallowing. (B) A “palatal drop prosthesis” can help improve articulation and swallowing. (C) The palatal drop prosthesis helps improve palate-tongue contact and therefore improves function.

is insufficient, a “palatal drop prosthesis” can be used to improve the neotongue-palate contact (**Fig. 1.10**). This technique, although effective, is not well tolerated because most patients have been treated with radiotherapy, making retention of the obturator difficult.

Option for Management: Anterolateral Thigh Free Flap

The anterolateral thigh flap has gained great popularity for head and neck reconstruction because of its reliability and diversity.¹⁵ It is also associated with minimal donor-site morbidity relative to other donor sites.¹⁶ The bulk of the anterolateral thigh flap can be variable depending on the body habitus of the patient. In thin patients, adjacent vascularized fat or de-epithelialized skin paddle can be harvested and rolled under the skin paddle to increase bulk. More commonly, this donor site may provide too much bulk, and alternative sites such as the lateral arm or radial forearm will need to be considered. In the appropriate patient, the anterolateral thigh flap can provide an excellent donor site option.

Surgical Technique and Considerations

- ◆ After confirming negative margins, the reconstruction can be planned. In most cases, the oral tongue can be reconstructed transorally without the need for a midline mandibulotomy.
- ◆ If there is no connection between the floor of mouth and the neck, a tunnel should be created to pass the vascular pedicle from the oral cavity into the neck where the microvascular anastomosis will be performed.
- ◆ The flap can be designed in a shape that accommodates the defect. Fat can be harvested with the flap to improve the bulk, and in patients who have been previously treated with radiation, muscle can be harvested to improve healing.

- ◆ Once the flap is inset, the microvascular anastomosis can be completed.

Patient Selection and Perioperative Management

The most common problem with complete oral tongue reconstruction is anterior ankyloglossia. This creates difficulty with both articulation and swallowing. The oral phase of swallowing requires that the tongue force the food bolus into the posterior aspect of the oral cavity. Ankyloglossia inhibits this mechanism, and patients often complain of food being stuck in their mouth and being unable to initiate the pharyngeal phase of swallowing. The bulk of the anterolateral thigh flap may be important in achieving neotongue-to-palate contact but may impede anterior neotongue mobility. In patients with bulky thigh tissue, the radial forearm with a vascularized fat flap may represent a better option.

Postoperatively, the patient is kept NPO for 7 days. We initiate swallowing exercises on postoperative day 5 followed by an oral diet trial on postoperative day 7.

Option for Management: The Radial Forearm Free Flap

The total oral glossectomy can be managed with the radial forearm flap if vascularized fat is harvested with the flap to achieve and maintain the bulk of the oral neotongue. The advantages of the radial forearm donor site include the ability to reinnervate the flap, and the pliability of the tissue lends itself to the complex contours of the floor of mouth.

Surgical Technique and Considerations (Fig. 1.11)

- ◆ Once the ablation has been completed and the margins have been assessed, the flap can be designed. When the entire oral tongue has been resected, the

flap can be designed with a wide skin paddle to accommodate the floor-of-mouth lining. The wide design also provides the architecture necessary to maintain the height of the flap within the oral cavity.

- ◆ The flap should be designed with a strip of vascularized fat to maintain the bulk. This will improve speech and articulation.

- ◆ The skin paddle can be sutured to the remaining floor of mouth mucosa with absorbable suture.
- ◆ During the resection, effort should be made to preserve the innervations to the base of tongue. This will significantly improve both articulation and swallowing.
- ◆ If the flap is designed with the appropriate redundancy to prevent tethering, the tongue will maintain mobility.

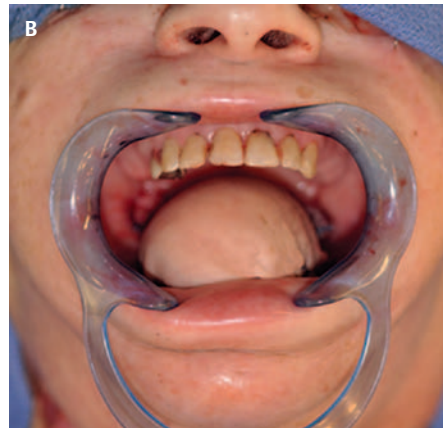
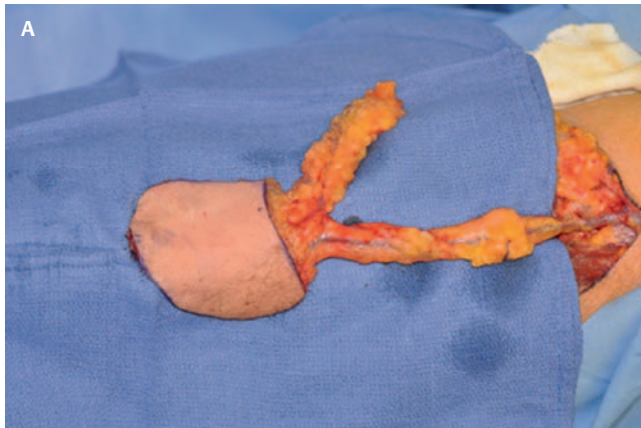


Fig. 1.11 (A) Clinical case. The total oral tongue defect can be reconstructed with a radial forearm free flap and a vascularized fat graft for bulk. (B) To prevent tethering of the neotongue, extra skin should be planned in the flap design to account for the floor of mouth lining. (C) One year postoperative view demonstrates preservation of the neotongue bulk. (D) The flap is designed to allow the patient to withdraw the neotongue and to protrude the neotongue (E). This mobility is essential for optimizing function.

Patient Selection and Perioperative Management

Although there are a variety of donor sites that can be used to reconstruct the total oral tongue defect, the radial forearm flap is ideal when there is extensive subcutaneous fat in the anterolateral thigh donor site. The pliable tissue of the radial forearm does not restrict mobility of the tongue.

Postoperatively, the patient remains NPO during the healing period of 7 to 14 days. We then institute aggressive swallowing therapy to encourage base-of-tongue motion and swallowing.

◆ THE TOTAL GLOSSECTOMY DEFECT

Historically, the pedicled pectoralis¹⁷ and latissimus dorsi flaps were used for total tongue reconstruction. Both flaps provide a reliable source of epithelial lining; however, these flaps tend to sink deep within the mandibular framework over time. Although, at first glance, reconstruction of the total oral tongue defect appears to be relatively straightforward, there are several potential pitfalls that should be considered. First, flap bulk is an absolute necessity to optimize speech and airway protection. Although the anterolateral thigh, rectus abdominis, and latissimus flaps all provide an appropriate source of bulk, if the flap is not supported, it will settle under the influence of gravity and withdraw, resulting in an oral “gullet.” The position of the flap can be supported with a mandibular sling (Fig. 1.12). Second, if laryngeal preservation is intended, a “stove-pipe” epiglottoplasty should be created to protect against aspiration (Fig. 1.13). The

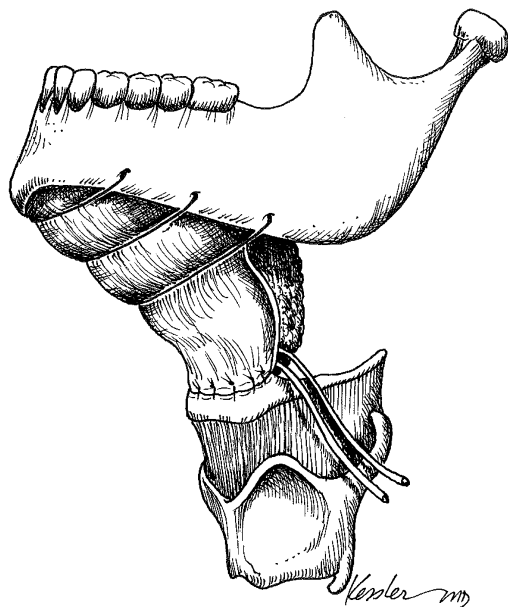


Fig. 1.12 The mandibular sling. If not supported, the myocutaneous flap will sink downward over time, resulting in a poor functional result. Nonabsorbable sutures can be arranged as a sling to support the flap and maintain the flap height and bulk.

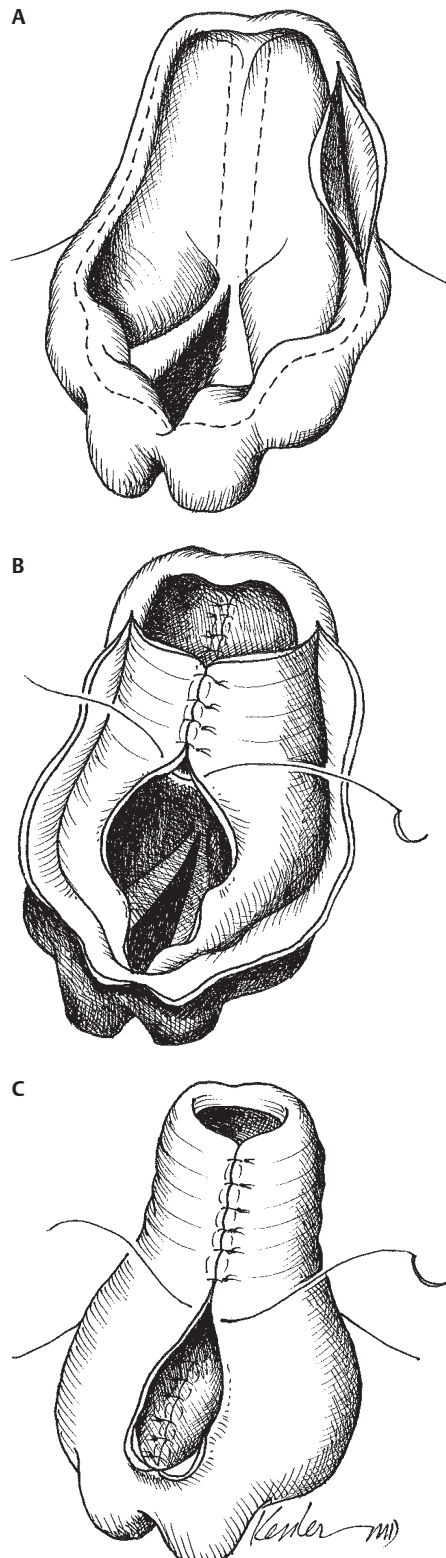


Fig. 1.13 (A) The epiglottoplasty is performed by first removing a strip of vertically oriented epiglottic cartilage to facilitate folding of the epiglottis. The aryepiglottic fold is incised to expose the peripheral edges of the cartilage. (B) A three-layer closure is performed with absorbable suture. This includes the inner mucosal lining, the cartilage closure, and the outer mucosal lining. (C) The final result is a “stove pipe” epiglottoplasty.

combination of a thoughtful reconstruction and a motivated patient can result in an excellent functional result.

Option for Management: Rectus Abdominis Free Flap

The rectus abdominis flap provides several important advantages over other donor sites for total oral tongue reconstruction.¹⁸ In addition to bulk, this donor site provides vascularized muscle and fascia, which help in healing and support of the floor of mouth. Typically, a total oral glossectomy is performed as a salvage procedure following initial chemoradiotherapy. As a result, vascularized muscle can be helpful in achieving healing in the compromised wound.

Surgical Technique and Considerations (Fig. 1.14)

- ◆ Once the ablative portion of the procedure is complete, the reconstruction is started by performing an epiglottoplasty. The epiglottoplasty is essential for laryngeal preservation following a total glossectomy to protect the airway and prevent aspiration.
- ◆ The rectus abdominal flap should be designed in the vertical orientation with enough length to accommodate the oral cavity reconstruction and the base of tongue reconstruction.
- ◆ The flap is oriented so that the vascular pedicle is positioned inferiorly and can be aligned with the transverse cervical vessels.
- ◆ The rectus fascia can be secured to the mandible by making a series of holes in the inferior edge of the mandibular ramus. This technique establishes a platform to support the bulk of the flap and helps to maintain the oral volume.
- ◆ The microvascular anastomosis can be completed after the flap has been sutured into the defect.
- ◆ In the case of laryngeal preservation, a hyoid advancement can be performed to raise the larynx and minimize the risk of aspiration (Fig. 1.15).

Patient Selection and Perioperative Management

A total glossectomy can be performed either with a laryngectomy or with laryngeal preservation. Although the stove pipe epiglottoplasty can be used to protect the airway in an effort to preserve the larynx, this approach is less reliable in patients who have been treated with prior radiotherapy. Not uncommonly, the epiglottoplasty may breakdown if the tissue is compromised by radiotherapy.

Postoperatively, we recommend that a cuffed inflated tracheotomy be kept in place for 10 days to promote healing. Swallowing and speech therapy are initiated 12 to 14 days postoperatively.

◆ THE BUCCAL DEFECT

The buccal mucosal defect can be managed with a variety of techniques, such as the split-thickness skin graft, the submental island flap, or a radial forearm free flap. The split-thickness skin graft provides a simple and effective approach for small defects of the buccal region. However, when a skin graft is used for larger defects, the graft often contracts, resulting in trismus. The submental island and radial forearm free flaps provide a source of lining that tends to contract less than a skin graft and therefore serves as a better option for larger defects.

Option for Management: Split-Thickness Skin Graft (Fig. 1.16)

The split-thickness skin graft provides a proven method for buccal reconstruction but often suffers from progressive chronic contracture. When a skin graft is used, meshing helps to minimize contracture and scar formation.

Option for Management: Submental Island Flap

The submental island flap provides a source of hearty tissue for head and neck reconstruction and serves as an option for floor-of-mouth, buccal, and select oral tongue defects.¹⁹ Because the submental lymph node basin is at high risk for metastasis from oral cancer, we avoid it for primary reconstruction and limit its use to secondary reconstruction of scar band–related trismus.

Surgical Technique and Considerations (Fig. 1.17)

- ◆ Once the defect is determined, the flap can be designed. The flap should be planned with an area 30% larger than the area of the defect to accommodate contraction associated with healing.
- ◆ The flap should be raised and set aside to perfuse before it is rotated into the buccal space.
- ◆ The flap can be tunneled lateral to the mandible or medial to the mandible if there is a floor of mouth defect.
- ◆ The flap inset can be performed transorally or through a midline lip-splitting incision to improve access in those cases where the trismus is significant.
- ◆ The flap can be sutured into the buccal space with absorbable suture, and the donor site can be closed primarily.

Patient Selection and Perioperative Management

Patients with a history of a neck dissection should be carefully approached because the dissection may be difficult and the vascular supply to the submental island flap may be

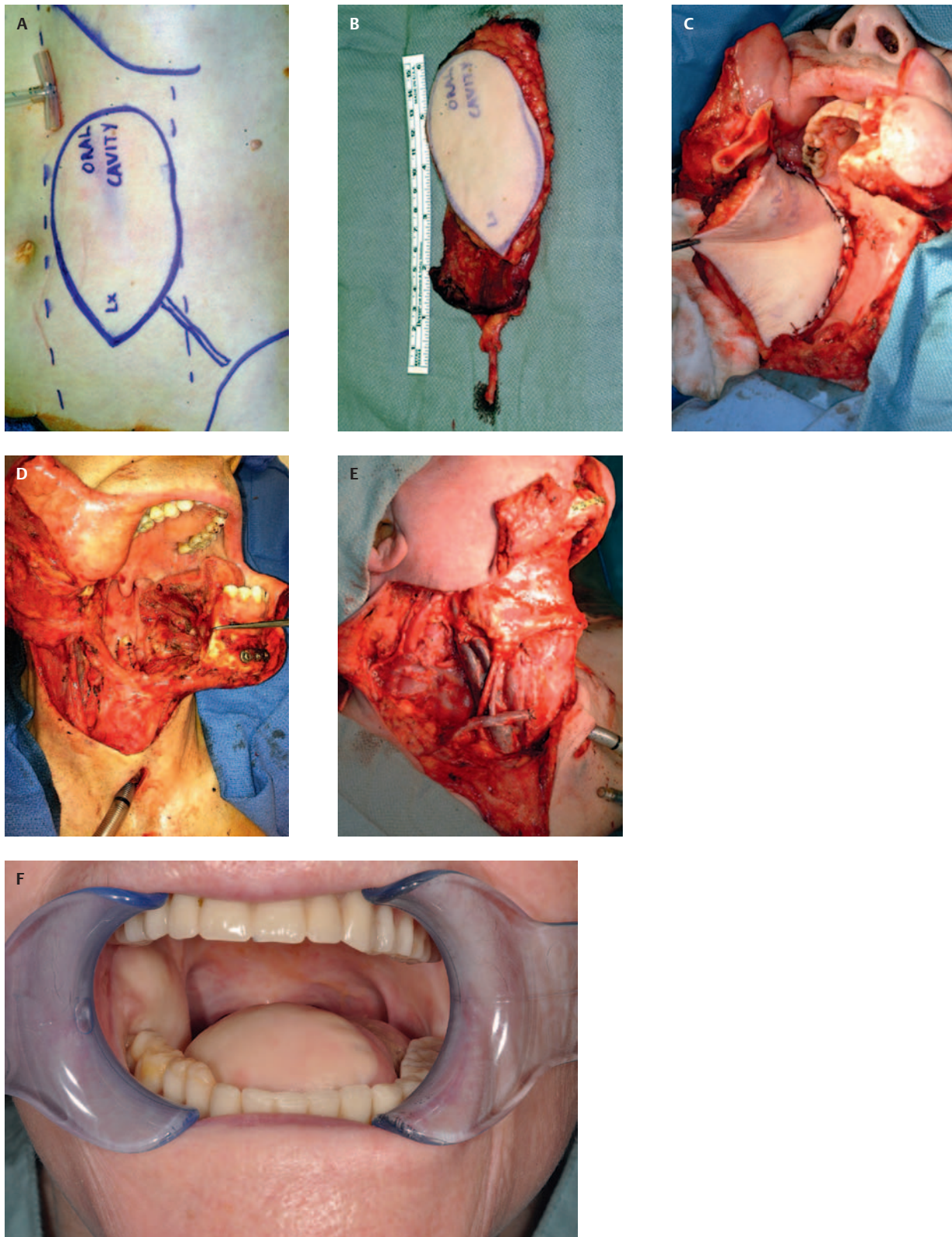


Fig. 1.14 (A) Clinical case. Reconstruction of the total tongue defect can be accomplished with the rectus abdominis flap. The flap design should provide enough skin for the oral tongue and the base of tongue. (B) The rectus abdominis flap provides a long vascular pedicle and muscle that is helpful on the irradiated patient. (C) The flap is sutured into the defect with interrupted absorbable suture. (D) To prevent postoperative aspiration, a tubed epiglottoplasty can be performed. (E) The closure should be completed so that the vascular pedicle is aligned to the transverse cervical vessels to prevent kinking. (F) Eight-month postoperative view demonstrates that neotongue volume is maintained as a result of the mandibular sling.

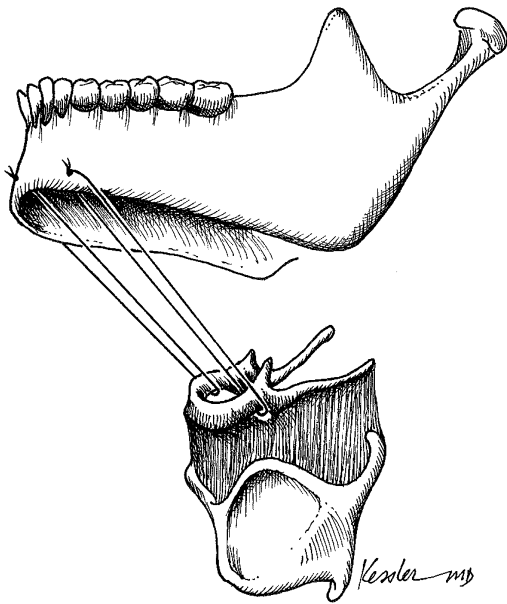


Fig. 1.15 The hyoid advancement is performed by placing a nonabsorbable suture around the hyoid and anchored to the inferior edge of the mandible. This technique acts to raise the mandible and improve swallowing.

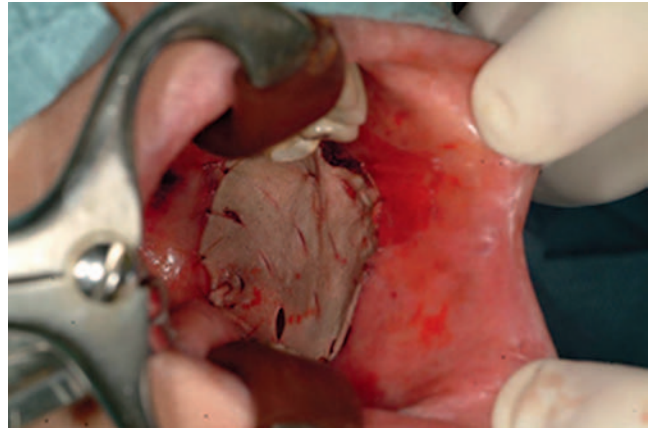


Fig. 1.16 Clinical case. Split-thickness skin graft for a superficial buccal reconstruction.



Fig. 1.17 (A) Clinical case. The submental island flap can be used for the buccal defect. **(B)** The submental island flap can be placed medial or lateral to the mandible. The full-thickness nature of the flap means that there is minimal contracture with healing.

compromised. Similarly, those patients with active malignant disease of the oral cavity and buccal region should be carefully assessed for level I and II metastasis before considering this approach. There is a risk of transferring lymphatic metastases within the flap.

Perioperatively, patients have a drain placed in the donor site that can be removed after 1 to 2 days. Patients should remain NPO for 5 to 10 days based on their degree of exposure to radiotherapy.

Option for Management: Radial Forearm Free Flap

The radial forearm flap can be applied to large defects of the buccal mucosa and buccal defects that extend on to the alveolus or maxilla. Unlike the skin graft technique, free tissue transfer tends to contract and scar less. In cases of secondary reconstruction where the patient presents with a preexisting trismus, a coronoidectomy or masseter lysis may be helpful to restore a normal opening.

Surgical Technique and Considerations (Fig. 1.18)

- ◆ Once the surgical margins have been confirmed, the flap can be designed. We recommend a flap that is slightly larger in surface area than the defect to compensate for scarring.
- ◆ The flap vascular pedicle can be drawn into the neck medial or lateral to the mandible. Once this has been decided, a tunnel should be achieved to pass the vascular pedicle into the neck.
- ◆ After the flap has been harvested, the skin paddle can be sutured into the buccal defect and the vascular pedicle can be drawn through the tunnel into the neck.
- ◆ If the parotid duct has been compromised during the ablative procedure, the duct can be marsupialized to

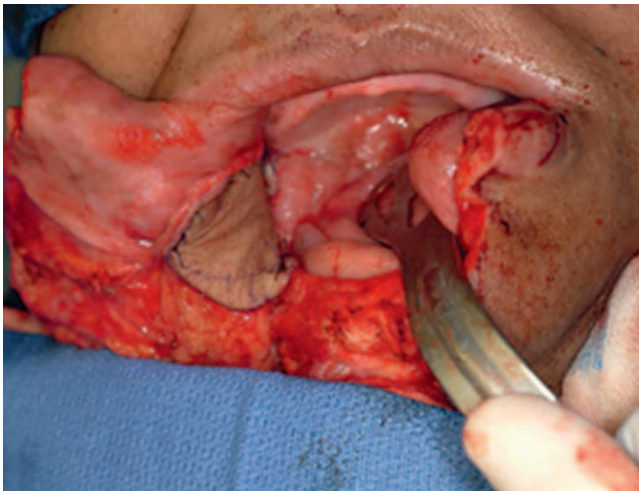


Fig. 1.18 The radial forearm represents another approach to buccal reconstruction. The flap should be designed 20% larger than the defect to account for healing and mild contracture.

preserve salivary flow. If possible, the duct can be placed between the flap and the native buccal mucosa interface; otherwise a perforation can be made in the flap to accommodate the duct.

- ◆ The vascular anastomosis can be performed in the final stage of the reconstruction.

Patient Selection and Perioperative Management

The radial forearm flap can be used in most cases where there is concern of contracture. Postoperatively, patients should be kept NPO for 7 to 10 days.

◆ THE SOFT PALATE DEFECT

The soft palate defect can result in a functionally devastating speech and swallowing deficit if not addressed at the time of ablative surgery. Although an oral obturator can be used, an airtight seal is often difficult to achieve, and therefore nasopharyngeal reflux and velopharyngeal insufficiency are common. Many patients treated primarily with surgery require adjuvant radiotherapy, and many patients undergoing salvage surgery already have been treated with external beam radiotherapy. In both situations, an obturator can be difficult to retain because of xerostomia, pain, and constantly changing anatomy associated with scar contracture. Ideally, a surgical reconstructive option has the potential to achieve palatal closure without the use of an obturator.

The best functional results are obtained when the muscles of the velopharynx are reapproximated to achieve a dynamic muscular sphincter. Resurfacing the soft palate anatomy with a soft tissue flap without reconstituting the muscular sphincter fails to achieve a durable functional outcome.

◆ THE HEMI-SOFT PALATE DEFECT

Option for Management: Muscular Velopharyngoplasty and Radial Forearm Free Flap

The combination of a muscular velopharyngoplasty and a radial forearm flap reconstruction can result in excellent function.²⁰ Although other soft tissue flaps can be used, the thin tissue of the radial forearm is ideal for pharyngeal reconstruction.

Surgical Technique and Considerations (Fig. 1.19)

- ◆ Once the resection margins have been assessed, the reconstruction is started by reconstituting the muscular sphincter. In those cases where a hemipalatectomy has been performed, the cut edge of the soft palate should be sutured to the cut edge of the posterior pharyngeal mucosa with 2.0 absorbable suture.

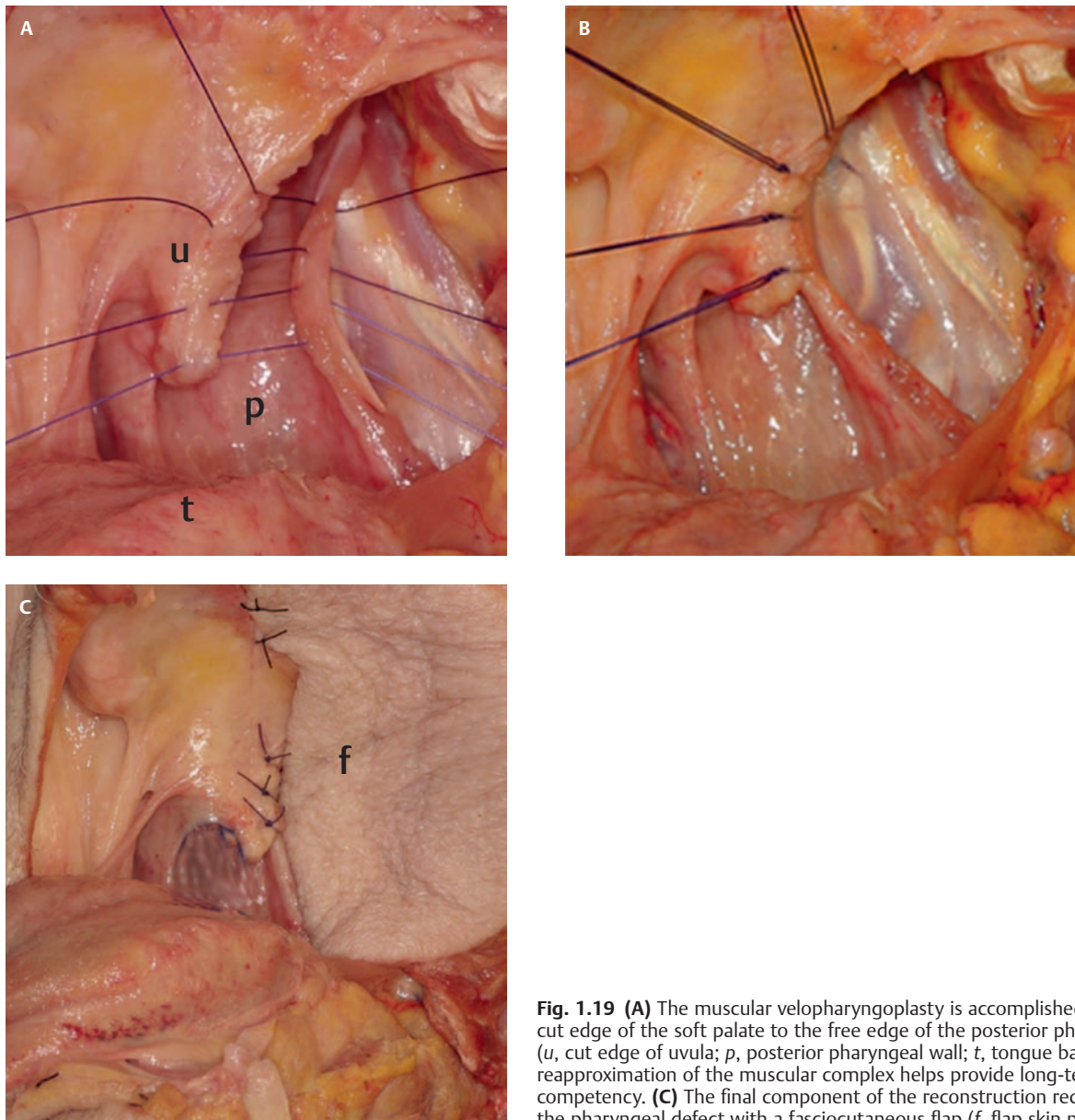


Fig. 1.19 (A) The muscular velopharyngoplasty is accomplished by suturing the cut edge of the soft palate to the free edge of the posterior pharyngeal wall (u, cut edge of uvula; p, posterior pharyngeal wall; t, tongue base). (B) The reapproximation of the muscular complex helps provide long-term velopharyngeal competency. (C) The final component of the reconstruction requires coverage of the pharyngeal defect with a fasciocutaneous flap (f, flap skin paddle).

- ◆ The palatal-pharyngeal defect can then be relined with a radial forearm flap. The design of the flap should accommodate the defect without redundancy.
- ◆ The vascular pedicle can be directed through the pharyngeal defect into the neck.
- ◆ The vascular pedicle typically aligns with the transverse cervical vessels for the microvascular anastomosis.

Patient Selection and Perioperative Management

The patients best suited for this reconstructive technique are those with a hemipalatectomy defect so that the muscular sphincter can be reestablished. Postoperatively, the patient

should remain NPO for 7 to 10 days. Although some clinicians have advocated nasopharyngeal stent, we have found that a stent does not prevent stenosis long term.

◆ THE TOTAL SOFT PALATE DEFECT

Option for Management: Palatal Adhesion and Radial Forearm Free Flap

Unlike the hemipalate defect, the total soft palate defect leaves no palatal tissue to reconstitute the velopharynx. As a result, a dynamic velopharynx cannot be reestablished



Fig. 1.20 The total palatal defect can be lined with a fasciocutaneous flap but requires a posterior pharyngeal wall adhesion to prevent velopharyngeal insufficiency.

unless a muscular transfer is performed. Although other soft tissue flaps can be used, the radial forearm is best suited for soft palate reconstruction because it is pliable enough to achieve the soft tissue reconstruction and the posterior pharyngeal adhesion.

Surgical Technique and Considerations (Fig. 1.20)

- ◆ Once the resection margins have been assessed, the radial forearm flap should be designed. The design of the flap should accommodate the defect without redundancy.
- ◆ The radial forearm should be designed to reconstitute the anatomy of the soft palate.
- ◆ Once the flap has been sutured into place, an area of the flap in the midline should be de-epithelialized along with an area along the posterior pharyngeal wall adjacent to the flap. This serves as the area where the adhesion will be performed.
- ◆ The adhesion between the flap and the pharyngeal wall can be sutured with 2.0 or 3.0 absorbable Vicryl suture.
- ◆ The vascular pedicle can be directed through the pharyngeal defect into the neck.
- ◆ The vascular pedicle typically aligns with the transverse cervical vessels for the microvascular anastomosis.

Patient Selection and Perioperative Management

Postoperatively, a nasogastric tube should be avoided so as not to disrupt the adhesion. We recommend peripheral parenteral nutrition for 5 days before beginning an oral diet.

◆ RECONSTRUCTION OF THE MAJOR LIP DEFECT

Reconstruction of lip defects presents the dual challenges of cosmetic and functional restoration. The lips are a prominent feature of the facial architecture and their form is often a focus of aesthetic appreciation. Their mobility and sphincteric function are key elements in facial expression, oral competence, and communication. As lip defects progressively increase in size, so too does the task of achieving an optimal reconstructive result. Reconstructive options available include simple primary closure, local flaps, regional pedicled flaps, and even free tissue transfer. Historically, early attempts at repair involved cross-lip flaps for relatively smaller defects eponymously credited to and popularized by Estlander in Europe and Abbe in North America. Larger defects required the transfer of advancement and rotation flaps from the adjacent melolabial region in a unilateral or bilateral fashion. Notable circumoral advancement flaps are the Gillies, Bernard, and Karapandzic flaps as well as their many modifications that are still commonly utilized today. Furthermore, the use of combined flaps along with the advent of microvascular free tissue transfer has allowed for additional reconstructive options for major lip defects in efforts to optimize aesthetic and functional patient outcomes.

◆ THE UPPER LIP DEFECT

The upper lip plays a significant role in overall facial aesthetics, expression, verbal communication, and mastication. It is separated by the philtrum into a median and two lateral aesthetic subunits.²¹ Lesions can involve one or more of these subunits and can result in superficial cutaneous as well as full-thickness lip defects. Trauma, infection, congenital malformation, and malignancy are the most common causes. The goals of reconstructive surgery should focus on optimizing cosmetic and functional outcomes. Techniques centered around the principles of dynamic reconstruction allow for the maintenance of oral competence and facial symmetry while facilitating speech and eating. Common methods of reconstruction range from simple primary closure to microvascular free tissue transfer and depend on the extent and location of lip defects in addition to patient-specific factors. Preoperative planning is critical to appropriately address and manage patient concerns, preferences, and expectations in an effort to maximize the ultimate reconstructive outcome.

Option for Management: Primary Closure or Local Advancement Flaps

Full-thickness defects involving up to one third of the upper lip can generally be addressed by primary closure. Resections are typically performed by full-thickness incisions in a V- or W-shaped design, with the apex extending as far as the melolabial crease. Centrally located defects that are less than

one third of the upper lip may be better reconstructed by local advancement flaps. Examples of these include vermilion, bilateral, or V-Y advancement flaps. It is important to choose a reconstructive option that maintains the relationship of the upper lip to its neighboring structures, namely the columella, nasal ala, melolabial crease, and cheek.

Surgical Technique and Considerations

- ◆ Relaxed skin tension lines should be considered when planning the incision to achieve an optimal cosmetic result.
- ◆ Primary closure should be performed in three layers: inner mucosa, orbicularis oris, and skin. Repair begins with precise approximation of the orbicularis to avoid notching and retraction.
- ◆ Careful realignment of the vermilion border is critical for cosmesis. It should be marked preoperatively for easy identification following surgical manipulation.

Patient Selection and Perioperative Management

Full-thickness defects of less than one third of the upper lip are generally the result of trauma or cutaneous malignancy. Reconstruction can typically be performed by primary closure after freshening of wound edges and achieving negative margins in trauma and oncologic cases, respectively. A variety of local advancement flaps can also be utilized for centrally located upper lip defects with favorable outcomes. Creation of microstomia during this repair should alert the surgeon that the defect is too large to be closed primarily and an alternative reconstructive technique should be employed.

Option for Management: Transoral Cross-Lip Flaps (Abbe and Estlander)

Full-thickness defects between one third and two thirds of the upper lip are generally repaired with either a transoral cross-lip or a circumoral advancement-rotation flap (**Fig. 1.21**). The transoral cross-lip technique was initially devised by Sabattini²² and later modified by Abbe²³ and Estlander²⁴ in the 1800s. This staged flap is based on the vascular supply provided by the labial artery and depends on local tissue for venous return. The Abbe flap is utilized for medially based lip defects, whereas the Estlander flap is employed for defects involving the commissure.

Surgical Technique and Considerations

- ◆ Flaps should be designed, when possible, to incorporate the melolabial crease in the donor site so that the incision is better camouflaged (**Fig. 1.21**).
- ◆ The length of the flap should equal that of the defect, whereas the width should be one half of the defect. A



Fig. 1.21 Extensive upper lip defect. A lip switch is planned.

notable exception to this is when reconstructing the central upper lip subunit. It is critical to design the donor flap with an equal width to ensure an optimal philtral contour (**Fig. 1.22**).



Fig. 1.22 Full-thickness defects between one third and two thirds of the upper lip are generally repaired with either a transoral cross-lip or circumoral advancement-rotation flap. In this clinical case, the lip is reconstructed with a transoral lip-switch approach.



Fig. 1.23 The flap is set into the defect.

- ◆ Abbe flaps may be pedicled medially or laterally and are two-stage procedures, requiring division of the vascular pedicle 2 to 3 weeks after the initial repair.
- ◆ Estlander flaps are one-stage procedures that may result in distortion or blunting of the involved commissure, necessitating a commissuroplasty (**Fig. 1.23**).
- ◆ The long-term result is typically excellent, providing favorable scarring and excellent function (**Fig. 1.24**).

Patient Selection and Perioperative Management

Transoral cross-lip flaps are well suited for reconstruction of medium-sized full-thickness defects of the upper lip that may or may not involve the oral commissure. Benefits are the hearty vascular supply of the flaps based on the labial artery and the good contour match provided by the normal tissue of the opposing lip. Preoperative planning should focus on preservation of the vascular pedicle, management of the commissure, and minimizing donor-site incisions. One significant drawback is the requirement of a second procedure 2 to 3 weeks postoperatively to divide the vascular pedicle, during which time the patient should adhere to a liquid or soft diet. In addition, both flaps are denervated during harvest, and return of sensation occurs slowly after several months, with a resulting risk of allodynia that is normally self-limiting; motor function is variable.

Option for Management: Nasolabial (Melolabial) Flap

Small to medium-sized cutaneous and full-thickness defects of the upper lip may also be repaired with the nasolabial or

melolabial flap.²⁵ The flap can be designed as a transposition-rotation or advancement flap depending on the size and location of the lip defect. The latter is a true pedicled flap based on the superior labial artery and is ideal for centrally based defects as well as a wide range of other reconstructive applications.

Surgical Technique and Considerations

- ◆ The nasolabial flap involves bilateral excision of elliptical segments of the nasolabial folds to permit advancement into the defect.
- ◆ The incision is designed at the base of the defect and extends onto the ipsilateral nasolabial crease for maximal advancement length and cosmesis.
- ◆ After appropriate undermining, the flap is advanced medially, carrying the oral commissure along with it.
- ◆ The nasolabial flap may be combined with a cross-lip flap such as the Abbe for reconstruction of larger centrally based defects.

Patient Selection and Perioperative Management

Patients with small to medium-sized central upper lip defects are suitable candidates for a nasolabial flap. The benefits are a single-stage procedure, linear closure, minimal donor-site morbidity, and good color match. Although a major drawback is the potential for denervation and resulting oral incompetence, modifications have allowed for potential postoperative function. The flap may be designed as a transposition flap or a true pedicled advancement reconstruction by subcutaneous dissection that may



Fig. 1.24 Six-month postoperative view demonstrates an excellent result.

preserve innervation and facilitate some degree of dynamic capability. Although initially described for upper lip repair, the nasolabial flap has also been applied to reconstruction of the lower lip, nose, cheek, lower eyelid, and commissure.

Option for Management: Circumoral Advancement-Rotation Flaps (Gillies and Reverse Karapandzic)

Full-thickness defects between one third and two thirds of the upper lip can also be addressed with a circumoral advancement-rotation flap. The Gillies fan flap involves a modification of the cross-lip flap and is also based on the labial artery, but can be performed as a single-stage procedure.²⁶ This flap is typically utilized for laterally based defects, but central subtotal defects can also be repaired with bilateral fan flaps. The reverse Karapandzic flap is a modification of the technique typically utilized for reconstruction of similar lower lip defects (see corresponding section for The Lower Lip Defect).²⁷ This flap uniquely offers superior sensory and motor function through preservation of the underlying neurovascular bundles with the potential risk of microstomia due to the necessary bilateral advancement.

Surgical Technique and Considerations

- ◆ The Gillies fan flap is a single-stage procedure based on the labial artery permitting primary closure of the donor site. It involves the advancement of a rectangular, full-thickness segment adjacent to the primary defect.
- ◆ The disadvantages include flap denervation, resulting in adynamic and insensate reconstructive tissue; however, delayed reinnervation may occur. The advancement also leads to a relative shift and blunting of the oral commissure.
- ◆ The flap is designed to encompass the nasolabial fold and cheek with the incision made in the melolabial crease for improved cosmesis. The length of the flap is determined by that of the defect and the width by the defect's height. The base of the pedicle should be located at the oral commissure.

Patient Selection and Perioperative Management

Circumoral advancement-rotation flaps such as the Gillies fan flap and reverse Karapandzic flap offer an alternative reconstructive option for medium-sized full-thickness defects of the upper lip. Both have the advantage of incorporating a large amount of adjacent lip and cheek tissue for a cosmetically acceptable one-stage repair in contrast to the staged cross-lip flap. Function can be preserved with the reverse Karapandzic technique, which provides the additional advantage of superior oral competence and mobility. Bilateral tissue advancement carries the risk of microstomia that may require secondary commissuroplasty and should be discussed with patients preoperatively. Circumoral advancement flaps also may not be acceptable in those who

wear dentures or other rigid oral appliances due to the shift in the oral commissure.

Option for Management: Free Tissue Transfer

The use of the local flaps in lip reconstruction becomes challenging as the size of the defect increases. Microvascular free tissue transfer provides the reconstructive surgeon with another option for total loss of the upper lip (**Fig. 1.25**). This allows for a one-stage repair with varying amounts of tissue that can be tailored to the defect. Several series have demonstrated excellent functional outcomes.²⁸ The most commonly used donor site is the radial forearm,²⁹ although use of the anterolateral thigh, fibula, and free temporal scalp flaps have also been reported.³⁰

Surgical Technique and Considerations

- ◆ The radial forearm flap is based on the radial artery and can be designed to the exact dimensions of the lip defect. The palmaris longus tendon can be harvested concomitantly and should be secured to the modiolus. Alternatively, fascia lata can be harvested to serve this purpose.
- ◆ The vascular pedicle can be accessed and brought through the neck to align with a donor vessel for the microvascular anastomosis.
- ◆ Risks include those inherent to microvascular transfer including poor color match and tissue bulk, scarring and contracture, microstomia, and flap failure. Refinements



Fig. 1.25 Total upper lip defect.



Fig. 1.26 Six months after a radial forearm palmaris longus reconstruction. The patient demonstrates acceptable cosmetic results with excellent functional outcome.



Fig. 1.27 Six months after a radial forearm palmaris longus reconstruction, the oral cavity opening is not restricted.

in flap design have led to a significant improvement in the aesthetic outcome since these flaps were first introduced.

- ◆ Long-term outcomes demonstrate that this technique provides oral competence with minimal microstomia (**Figs. 1.26 and 1.27**).

Patient Selection and Perioperative Management

The advent of microvascular free tissue transfer has allowed for a reliable reconstructive option for total defects of the upper lip. Patients who wear dentures, have complex wounds, have defects involving multiple facial units, and have a history of radiation treatment are ideal candidates for free tissue transfer reconstruction. Proper preoperative workup specific to the free flap must be performed preoperatively, such as an Allen's test and a magnetic resonance angiography (MRA) of the upper and lower extremity, respectively. Postoperatively, we recommend that the patient be NPO and that aggressive oral hygiene be maintained for 5 to 7 days to facilitate healing. Dental restoration should not begin before 8 to 12 weeks, when the flap has healed to the deep tissue.

◆ THE LOWER LIP DEFECT

Similar to the upper lip, the lower lip is critical to overall cosmesis and functions such as eating, speaking, and facial expression. Additionally, the lower lip plays a relatively more important role in the maintenance of oral competence and prevention of drooling. Etiologies of lower lip defects are

varied but most often include trauma and neoplasm, as this area represents the most common location of primary cutaneous carcinomas due to increased direct sun exposure. The goals of reconstruction are to optimize form and function and range from simple primary closure to microvascular free tissue transfer. Ideally, reconstructive options should maintain the relationship to adjacent facial units, namely the upper lip, nasolabial crease, cheek, and chin. As in surgery for the upper lip, preoperative planning and individual patient factors must be thoroughly explored to maximize the ultimate reconstructive outcome.

Option for Management: Primary Closure

Full-thickness defects involving up to one third of the lower lip can generally be addressed by primary closure. This is a relatively larger area that can be closed primarily because of the fewer number of subunits and greater amount of tissue laxity in this region. Resections are typically performed by V-shaped excisions, with the apex not extending further than the mental crease. Incisions should be full-thickness and cross the vermilion border in a perpendicular plane.

Surgical Technique and Considerations

- ◆ Principles of reconstruction are similar to those for the management of upper lip defects. A three-layer closure, starting with the orbicularis oris muscle, and a meticulous closure of the vermilion and red lip are essential to an aesthetically pleasing outcome.
- ◆ In contrast with upper lip defects, advancement flaps are usually not necessary for small lower lip defects.

Patient Selection and Perioperative Management

Full-thickness lower lip defects result from trauma or ablative resections. Pathology reports should be obtained and reviewed to confirm that the resection margins are negative for tumor. Once negative margins are achieved, defects less than one third of the lower lip can be closed primarily. Larger defects result in microstomia, and local flaps are the favored reconstructive method.

Option for Management: Transoral Cross-Lip Flaps (Abbe and Estlander)

Full-thickness defects between one third and two thirds of the lower lip are generally repaired with either a transoral cross-lip or a circumoral advancement-rotation flap. The Abbe and Estlander flaps are used for both upper and lower lip reconstruction. The Abbe flap is utilized for medially based lip defects, whereas the Estlander flap is employed for defects involving the commissure. Distortion of the donor site is more common when using the upper lip because of its relationship to the philtrum, nasal sill, and ala.

Surgical Technique and Considerations

- ◆ Abbe and Estlander flap design is similar for upper and lower lip reconstruction: donor-site incisions should be camouflaged in the melolabial crease, the geometry of the donor site is the same, and a commissuroplasty may be indicated.
- ◆ The design of the Abbe flap should be based on the lateral upper lip subunit, if possible. This avoids distortion of the central upper lip and its relationship to adjacent facial units.

Patient Selection and Perioperative Management

Transoral cross-lip flaps are well suited for reconstruction of medium-sized full-thickness defects of the upper lip that may or may not involve the oral commissure. Benefits are the hearty vascular supply of the flaps based on the labial artery and the good contour match provided by the normal tissue of the opposing lip. Preoperative planning should focus on preservation of the vascular pedicle, management of the commissure, and minimizing donor-site incisions. One significant drawback is the requirement of a second procedure 2 to 3 weeks postoperatively to divide the vascular pedicle, during which time the patient should adhere to a liquid or soft diet. In addition, both flaps are denervated during harvest, and return of sensation occurs slowly after several months, with a resulting risk of allodynia that is normally self-limiting.

Option for Management: Circumoral Advancement-Rotation Flaps (Karapandzic and Gillies)

Full-thickness defects between one third and two thirds of the lower lip can also be addressed with a circumoral

advancement-rotation flap. The Gillies fan flap, as described in the previous section on reconstruction of the upper lip, can similarly be used for medium-sized lower lip defects. The Karapandzic flap was initially described as a method for lower lip repair based on local arterial flaps. Due to the preservation of the underlying neurovascular bundles, this widely utilized circumoral advancement flap offers superior sensory and motor function with the potential for a dynamic reconstruction.

Surgical Technique and Considerations

- ◆ The Karapandzic flap involves the rotation of remaining tissue adjacent to the primary defect around the commissure, thus avoiding a vascular pedicle that crosses the oral stoma and requires later division.
- ◆ The incision for the Karapandzic flap is placed in the nasolabial fold and continues around and beyond the oral commissure to communicate with the lower border of the lip defect (mentolabial crease) for improved cosmesis (**Fig. 1.28**).
- ◆ The skin and subcutaneous tissues are divided sharply, and the orbicularis oris is carefully dissected by separating the neurovascular bundles. This is typically most challenging near the oral commissure and is key to maintaining meaningful sensory and motor function (**Fig. 1.29**).
- ◆ The inner mucosal layer is left intact except for the distal end of the flap to facilitate advancement and closure (**Fig. 1.30**).
- ◆ Bilateral Karapandzic flaps can be used for the single-stage reconstruction of subtotal defects but they entail the risks of postoperative microstomia and the need for secondary commissuroplasty (**Fig. 1.31**).

Patient Selection and Perioperative Management

Circumoral advancement-rotation flaps such as the Gillies fan flap and Karapandzic flap offer an alternative

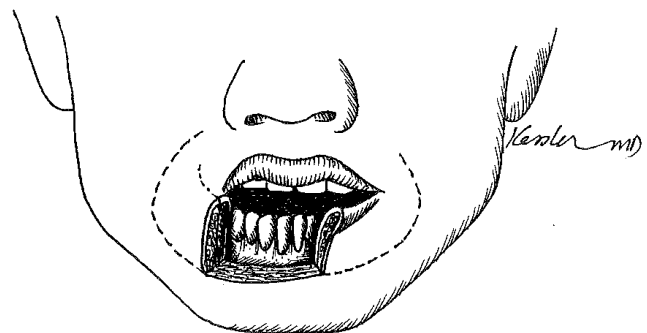


Fig. 1.28 Illustration of a Karapandzic flap for a defect comprising approximately two thirds of the lower lip. Perioral incisions are made bilaterally extending from the base of the defect out toward the cheek, around the oral commissure, and superiorly into the upper lip along the nasolabial folds.

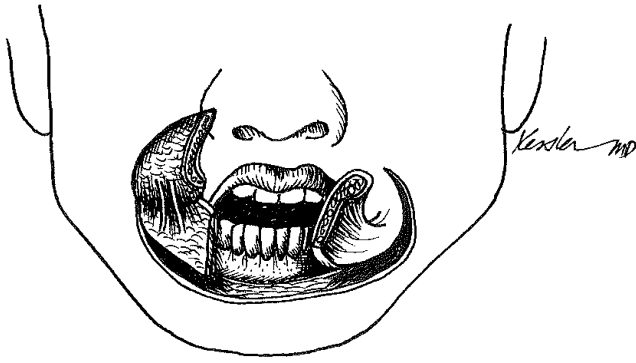


Fig. 1.29 Partial-thickness flaps are raised with meticulous dissection through the orbicularis oris muscle fibers, taking care to preserve the neurovascular supply to the flap. The inner mucosa is not violated except at the most distal aspect of the flap.

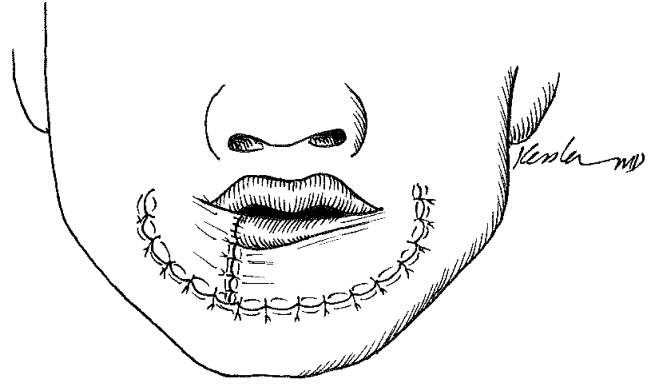


Fig. 1.31 A layered closure is performed, taking care to meticulously align mucosal edges along the vermilion border; a fine, nonabsorbable suture should be used for the skin.

reconstructive option for medium-sized full-thickness defects of the lower lip. Both have the advantage of incorporating a large amount of adjacent lip and cheek tissue for a cosmetically acceptable one-stage repair in contrast to the staged cross-lip flap. Function can be preserved with the Karapandzic technique, which provides the advantage of superior oral competence and mobility. Similar to the fan flap, bilateral tissue advancement carries the risk of microstomia, which should be discussed with patients preoperatively and may not be acceptable in those who wear dentures or other rigid oral appliances.

Option for Management: Bernard-Webster Flap

Total full-thickness lower lip defects may be repaired with the Bernard-Webster flap. This flap is a modification of the original Bernard-von Burow technique^{31,32} and involves the excision of four perioral triangles to create successive local advancement flaps. Innervation is typically not restored, so oral incompetence is often an issue postoperatively, although

this is more commonly encountered with repair of lower lip defects because of the nature of its functional contribution.

Surgical Technique and Considerations

- ◆ The Bernard-Webster flap involves the excision of partial-thickness (i.e., cutaneous) triangles to create local advancement flaps. Because these triangles are not full thickness, mucosal defects must be repaired separately (**Fig. 1.32**).



Fig. 1.30 After partial-thickness lip and cheek flaps are raised, the edges of the lower lip defect are advanced circumorally.

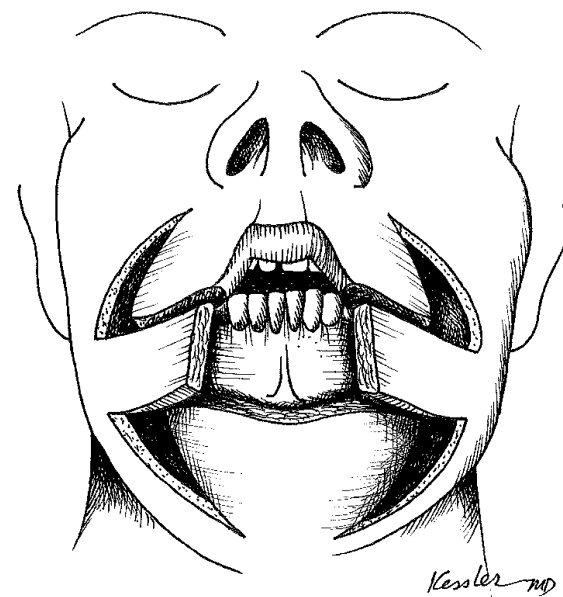


Fig. 1.32 Bernard-Webster flap for subtotal lower lip defect. Bilateral partial-thickness melolabial triangles are excised and labiomandibular incisions rather than triangles are created inferiorly from the inferolateral aspects of the defect.

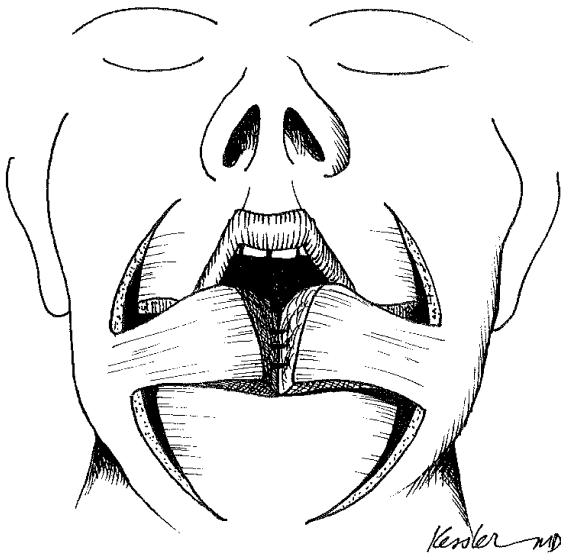


Fig. 1.33 After partial-thickness lip and cheek flaps are raised, the edges of the lower lip defect are advanced medially toward the midline facilitated by the lateral releasing triangles and incisions.

- ◆ Our group modifies the current technique by making bilateral labiomental incisions instead of excising partial-thickness labiomandibular triangles so as not to risk denervation of the depressor anguli oris (**Fig. 1.33**).
- ◆ The closure provides muscular competence and preserves the oral opening (**Fig. 1.34**).

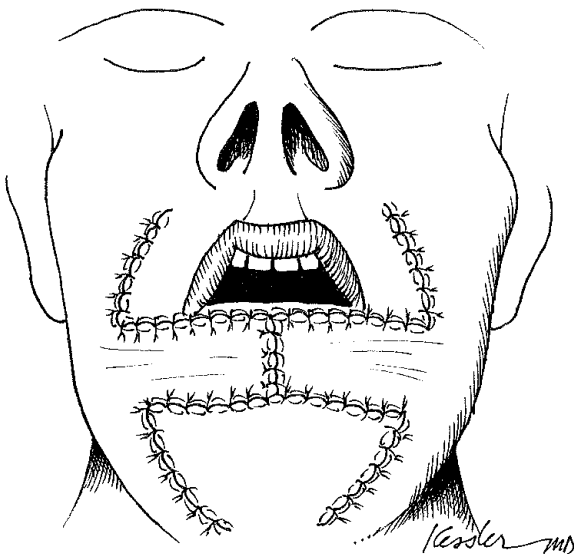


Fig. 1.34 A layered closure is performed, taking care to meticulously align mucosal edges along the vermilion border; a fine, nonabsorbable suture should be used for the skin.



Fig. 1.35 Subtotal lower lip defect after excision of carcinoma extending to the oral commissure on the left side.

Patient Selection and Perioperative Management

Subtotal and total lip defects present a significant reconstructive challenge (**Fig. 1.35**). Complex local advancement flaps such as the Bernard-Webster technique are an option but often result in an unsatisfactory degree of cosmesis and function due to the adynamic nature of the reconstruction. Although they are very useful in some cases, our group finds that microvascular free tissue transfer offers a consistently superior result for extensive lip defects. The Bernard-Webster flap can be reserved for patients who are not able to tolerate a lengthy operative procedure or would otherwise not be suitable candidates for free tissue transfer. The use of combined flaps such as the Bernard and a cross-lip or the Bernard-Webster and Karapandzic flaps may be a reconstructive option in certain cases.^{33,34} The novel use of a combined Karapandzic and Bernard-Webster flap for a near-total lower lip defect (**Fig. 1.36** and **Fig. 1.37**) does not require a



Fig. 1.36 A right-sided Karapandzic flap is raised with markings for a modified Bernard-Webster flap on the left side. Dissection is performed subcutaneously with preservation of the flap's neurovascular bundle; the inner mucosa is violated only at distal flap edges.



Fig. 1.37 The flaps are advanced together and closed in layers. Note the careful reapproximation of the vermilion border and the incisions lying in aesthetically acceptable areas (e.g., nasolabial fold, mentolabial crease).

secondary reconstructive procedure. The long-term cosmetic and functional results are excellent (**Fig. 1.38**).

Option for Management: Free Tissue Transfer

Microvascular free tissue transfer is used more commonly to repair total lower lip defects compared with upper lip

defects. A possible explanation for this is that carcinoma involves the lower lip more often than its counterpart. As such, ablative total lower lip defects occur more often. The principles of reconstruction are the same. Precise assessment of the three-dimensional conformation and volume is essential. The radial forearm free flap is the ideal choice for most defects.

Surgical Technique and Considerations

- ◆ Donor sites should be selected on the color match, texture, pliability, reinnervation potential, and size of the defect.
- ◆ The radial forearm free flap is usually harvested with palmaris longus tendon or fascia lata, which are then anchored to the modiolus and zygomatic body or arch.
- ◆ Composite free flaps, such as the fibula, or scapula. osteofasciocutaneous flaps, can be utilized for soft tissue and bony defects. These flaps are used more often in lower lip defects.

Patient Selection and Perioperative Management

Microvascular free tissue transfer is an established reconstructive option for large lip defects. Its indications are the same for the upper and lower lip. The main advantage of these flaps is that they entail a one-stage repair of large defects, especially in patients without tissue laxity. Oral competence and static function are limitations that need to be addressed in flap design.

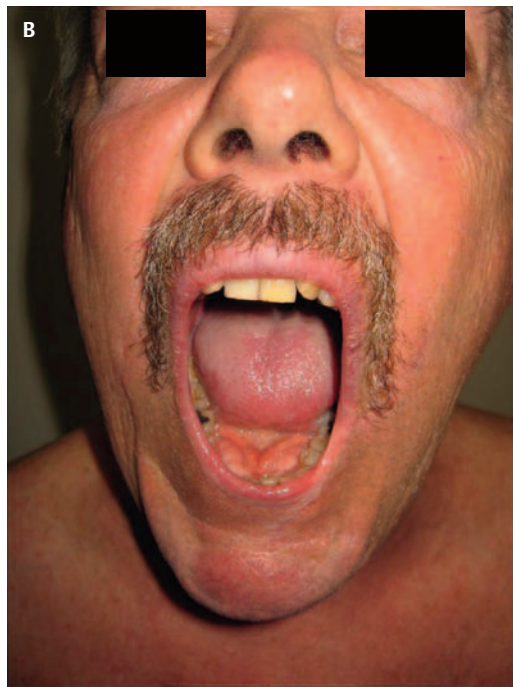


Fig. 1.38 (A,B) Two months postoperative from subtotal lower lip reconstruction. Microstomia is avoided along with additional corrective procedures using the combined advancement flap technique.

◆ CONCLUSION

Because the muscular and sensory dynamics of the oral cavity are vitally important to articulation and swallowing, thoughtful consideration must be given to the reconstructive plan. Mobility of the tongue, velopharyngeal competence, and oral volume are important concepts that should be accounted for when considering the options for reconstruction. Although a variety of donor sites provide tissue that is acceptable for oral cavity reconstruction, success is the result of careful planning and an understanding and appreciation of the potential for scar contractures that inevitably occur during the healing process.

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Oromandibular Complex Reconstruction

Eric M. Genden

The oromandibular complex plays an essential role in mastication, articulation, and cosmetic form. The mandible provides the support and foundation for tongue position and elevation of the larynx during swallowing. Similarly, the tongue and the adjacent buccal anatomy are responsible for articulation of speech and mastication. Oromandibular defects that result from trauma, congenital deformity, or tumor extirpation often have an impact on both form and function. The defect can range from a simple isolated bony defect to a complex defect involving the mandible, tongue, and soft tissue. As a result, the site of the defect and the associated soft tissue defect are the two most important factors in determining the impact of an oromandibular defect on a patient's function and aesthetics. These factors are also important in determining the most appropriate method of reconstruction.

Prior to the introduction of microvascular free tissue transfer, techniques such as free bone grafts, vascularized rib, and alloplasts were commonly employed to restore mandible defects; however, the results were often suboptimal. Many of the techniques were initially developed during the First World War when external fixation and free bone grafts were commonly used as part of a staged reconstruction. Because these techniques were used prior to the advent of antibiotics and rigid fixation, free bone grafts frequently resorbed or became infected.^{1,2} This was particularly common when defects communicated with the oral cavity because the salivary contamination often infected the bone graft before vascular ingrowth could occur. This contributed to the development of a sequestrum and a persistent fistula. Larger grafts and vascularized rib commonly suffered a similar fate, resorbing over time.

The advances in oromandibular reconstruction that followed the Second World War were largely a result of the introduction of both antibiotics and wire fixation. Although reconstructive surgeons were still dependent on free grafts, graft survival improved. In the 1960s and 1970s, prosthetic and allograft mandible reconstruction techniques became popular. Metallic trays filled with cancellous bone and

materials such as alloplastic mandibles created out of Silastic, Dacron, and Teflon were popularized; however, infection, exposure, and fracture were common, and these techniques were quickly abandoned.³⁻⁶

The introduction of the metallic reconstruction plate in the 1980s provided an improved method for stable fixation of free bone grafts⁷; however, because nonvascularized bone grafts were used, failure rates remained unacceptably high. Large free graft, in spite of fixation, failed to revascularize, and, as a result, they became weakened and were resorbed. In an early attempt to provide a vascularized bone graft, the pectoralis myocutaneous flap was designed with a segment of vascularized rib. Early results were promising, but longer term results were less encouraging.⁸

In the mid-1970s, vascularized mandibular reconstruction was introduced and has subsequently become the standard of care for patients with extensive defects of the jaw.⁹ Initial reports using the vascularized iliac crest were subsequently followed by descriptions of the scapular and fibular donor sites.¹⁰⁻¹² Each donor site is distinctly unique. The iliac crest, initially described in association with the groin flap, provides a source of hearty bone stock, vascularized internal oblique muscle, and skin. The vascular supply is the deep circumflex iliac artery and vein. This donor site was especially popular in the 1980s prior to the introduction of the fibular donor site; however, it is less commonly used now because of a variety of drawbacks. Although this tripartite flap provides an excellent source of bone for osseointegration, shortcomings including a short vascular pedicle, the poor reliability of the skin paddle, and the lack of segmental perforating blood vessels, limiting the surgeon's ability to perform bone-shaping osteotomies, which has curtailed the popularity of this donor site.

In 1986, the scapular donor site was introduced for mandibular and maxillary reconstruction.¹³ Often referred to as the subscapular system of flaps, this donor site provides a system of flaps that are ideal for complex head and neck reconstruction. The subscapular artery and vein give rise to the circumflex scapular vessels and the thoracodorsal artery

and vein. Because of the rich vascular network, this donor site gives rise to two skin paddles, the parascapular (axial) and the scapular (transverse); two separate vascularized bone grafts, the lateral of the scapula and the scapular tip; and the latissimus dorsi muscle. Because of the wide variation of muscle, skin, and bone flaps, this donor site is often reserved for complex defects or when peripheral vascular disease precludes the use of the iliac or fibular donor sites. The shortcomings of this donor site are limited to the fact that it cannot be harvested using a two-team approach. In our experience, the bone stock is adequate for mandible and maxillary reconstruction.

The fibular donor site, introduced in 1989, has become the most popular donor site for mandible reconstruction because of its excellent bone stock, reliable anatomy, and the ability to harvest the flap as a two-team approach.¹² The flap is based on the peroneal artery and paired veins. The skin island is based on the perforating vessels, which travel within the posterior crural septum. The skin island can be positioned either intraorally or externally, and this flap can provide up to 25 cm of bone, enough to perform a total mandible reconstruction. Blood supply to the fibula is both intraosseous and segmental, allowing for multiple osteotomies. Although some suggest that the shortcoming of the fibular donor site is the unreliability of the skin island, we find that this occurs in less than 5% of cases.

◆ RELEVANT ANATOMY

Understanding the anatomy of the oromandibular complex is exceptionally important in determining the optimal approach to reconstruction of this unit. It is also important to understand the relationship between the structure of the mandible and the mobility of the tongue because it is this relationship that is crucially important to form and function of the oral cavity. The mandible serves as a foundation of the oromandibular complex.

Although the mandible is a single bone, it is actually composed of two fused hemi-mandibles joined by intramembranous ossification at the midline during development. The fusion of the two hemi-mandibles occurs by the first 24 months of life. The mandible is composed of a horizontal body with a posterior vertical extension termed the ramus.¹⁴ On the inner surface of the mandible are the paired superior and inferior mental spines, which represent the areas of attachment of the genioglossus and the geniohyoid muscles. Just lateral to the symphysis on the inner surface of the mandible are two paired protuberances termed the superior and inferior mental spines. The genioglossus muscle attaches to the superior mental spines, and the geniohyoid muscle attaches to the inferior mental spines. The mylohyoid line extends obliquely in a posterosuperior direction from the midline and serves as the attachment site for the mylohyoid muscle that supports the tongue and its associated structures.

On the medial surface of the ramus inferior to the mandibular notch is the mandibular foramen that transmits the inferior alveolar nerve and blood vessels. The lingual lies

medial to the mandibular foramen, pointing posterosuperiorly toward the condylar head. This landmark can be used to locate the inferior alveolar nerve in cases where the nerve can be preserved.

The ascending ramus articulates with the skull base at the glenoid fossa. The condyle of the mandible is secured within the glenoid fossa by the ligaments of the articular capsule. The articular capsule is a loose tissue envelope attached to the superior skull base and attached below to the neck of the condyle of the mandible. The other ligaments that secure the condyle of the mandible into the fossa include the temporomandibular and sphenomandibular ligaments. The temporomandibular ligament is attached above to the lateral surface of the zygomatic arch, and below to the lateral surface of the neck of the mandible. The sphenomandibular ligament is a thin band attached above to the spina angularis of the sphenoid bone and fixed below to the lingula of the mandibular foramen. The articular disk sits in the joint space between the condyle of the mandible and the mandibular fossa. The disk acts to promote free movement of the joint during speech and mastication.

The general understanding of the mandibular anatomy is important when considering reconstruction in order to preserve the biomechanics and function of the mandibular complex. Because the loading forces associated with mastication are significant, a general understanding of the mandible biomechanics is important to preserve function and form.

◆ BIOMECHANICAL CONSIDERATIONS

Factors that influence the biomechanics of the mandible include the integrity of the temporomandibular joint (TMJ), the bone stock distribution, and the forces associated with scar contracture. The mobility of the TMJ is extensive. The mobility of the TMJ allows for the mandibular depression, elevation, side-to-side movement, and anterior and posterior movement. The TMJ is often referred to as a single joint, yet actually there are two joint spaces, an upper and lower. During speech, the joint movement is confined to the lower of the two joints. When the mouth is opened widely during biting, the lower joint acts as a hinge, whereas the upper joint provides a gliding character. The hinging and gliding movements take place simultaneously during mastication as the condyle rotates on the joint disk. The preservation of the joint biomechanics is ideal during reconstruction of the mandible. Because the complex movements of the TMJ are difficult to reconstruct, the integrity of the joint should be preserved whenever possible. Yet even the most meticulous joint reconstruction fails to provide the complex hinge-gliding movements of the native joint.

The mandible itself is uniquely designed with increased bone stock along the inferior border and anterior aspect of the ascending ramus in response to the forces of mastication. When approaching a mandibular reconstruction, it is ideal to re-create these structures with the biomechanics in mind. A good example is during mandibular reconstruction where it is beneficial to reestablished the inferior border to

preserve the integrity of the biomechanical forces of chewing. In addition to the distribution of the bone stock density, the form and contour of the mandible are also important. The contour of the mandible is important to facial symmetry, and the continuity of the mandible is important to oral function. The mandibular arch, for example, serves to anchor the suprahyoid muscles, whereas the mandibular body anchors the mylohyoid muscle, which supports the position of the oral tongue. When either the body or the arch of the mandible is disrupted, the ability to raise the larynx during swallowing or the position of the tongue may be greatly affected, leading to a disturbance in swallowing, speech, and articulation.

Scar contracture is the most difficult biomechanical force to account for and often is the most disrupting. This is exemplified by debilitating trismus that often occurs after mandibular reconstruction and external beam radiotherapy. Because external beam radiotherapy is associated with an inflammatory phase during the treatment course and is subsequently followed by a healing phase that results in scar formation, it often causes an irreversible scar contracture of the temporalis muscle, whereas therapy may minimize the extent of the contracture that can cause trismus, shifting of the mandibular complex, and a painful and debilitating cross-bite deformity. In many cases a coronoidectomy performed at the time of the surgery is the most effective way to prevent this chain of events. Although temporalis contracture is rather easy to predict, masseter, pterygoid, and oropharyngeal contractures are more difficult to anticipate as well as more difficult to prevent and manage.

◆ CLASSIFICATION OF OROMANDIBULAR DEFECTS

Several classification systems have been proposed for the assessment of the mandibular defect^{15–18}; however, none has gained wide acceptance. The failure of any singular system to gain acceptance highlights the complexity of the bony and associated soft tissue anatomy. The first comprehensive classification system was published in the Russian literature by Pavlov¹⁵ in 1974. He reviewed 215 cases and divided the cases into three classifications based strictly on the bony defect. Pavlov's classification system was enlightening, as it recognized the functional and aesthetic importance of the anterior mentum and the condyle. Pavlov wrote, "The most important sign, the presence or the absence of the mental portion of the lower jaw, this largely determines the severity of the clinical picture and the functional disturbances and the complexity of the restorative operations and their results."¹⁵ The classification system, however, was simplistic and failed to recognize the concomitant mucosal defect.

The Mount Sinai Group introduced a classification system in 1991 that expanded on Pavlov's concepts and classified defects based on bone, soft tissue, and neurologic deficits.¹⁸ The complexity of this anatomic classification system was overwhelming, offering more than 3500 possible oromandibular defects. Although thorough, this system was too complex, making the design of a reconstructive algorithm impractical. The University of Toronto group subsequently proposed a simpler classification system using upper case

letters to denote the bony defect and lower case letters to convey the involvement of skin mucosa, skin, and the combination of skin and mucosa.¹⁷ But none of the published classification systems has caught on, and most reconstructive surgeons use a simple description to relate the extent of the defect. Although a classification system has the potential to provide a framework for a reconstructive algorithm, it has proven difficult to relate the functional and aesthetic complexity of a mandibular defect in a simple classification system.

◆ ASSESSING OROMANDIBULAR DEFECTS

Optimal outcomes in oromandibular reconstruction can only be achieved with careful presurgical preparation. When assessing an oromandibular defect, it is important to consider the predicted location of the bony defect, the extent of the associated soft tissue defect, and the plan for dental rehabilitation. The soft tissue defect is typically considered the most important factor when considering reconstructive options. For many years, tongue flaps, skin grafts, and primary closures were used to manage the soft tissue component of the oromandibular defect. These techniques often led to devastating functional deficits because of tethering of the tongue and impaired swallowing and articulation. Free flap lends the unique advantage of providing vascularized bone and a skin paddle that can be used to reconstruct the floor of mouth or tongue without interfering with articulation and swallowing. This is not to say that the extent of the bony defect is not important. In fact, the size of the bony defect will also play a role in determining the options for reconstruction. Bony defects less than 3 cm may be treated with free bone grafts if there is no defect in the lining of the oral cavity. In contrast, bony defects greater than 3 cm often require a vascularized bone containing free flap, especially if there is an oral mucosal defect. The complexity of the oromandibular complex and the wide range of potential combinations of bony and soft tissue defects make reconstruction of this area most challenging.

The plan for dental rehabilitation must be carefully considered well before surgery. Although tissue-borne dentures are common because of the financial burden of osseointegrated implants, implant-borne dentures provide the optimal oral-dental rehabilitation. In either case, the re-creation or preservation of a lingual-buccal sulcus is essential to establish retention of the denture. If osseointegrated implants are anticipated, a coordinated presurgical plan should be established with an oral maxillofacial surgeon and prosthodontist. This will facilitate planning of the implant placement that is essential for any stable dental restoration.

Finally, mandible reconstruction can be performed either primarily, at the time of extirpation, or secondarily, at a later date. Following the introduction of microvascular free flap reconstruction of the mandible, opponents suggested that primary reconstruction may obscure surveillance and prevent the early detection of recurrence. For this reason mandible reconstruction was advocated as a secondary procedure following a 2-year disease-free interval. Since the early 1990s, advances in imaging have improved surveillance

and demonstrated that when the combination of serial imaging and routine physical examination are instituted, primary mandible reconstruction does not adversely affect the early detection of recurrence. There are, however, circumstances when secondary mandible reconstruction may be considered. Specifically, in situations where the bone margins are in question, a secondary reconstruction may be considered. Other considerations include patients who are at high surgical risk because of medical comorbidities, and elderly patients who are frail. Although most surgeons prefer to perform primary mandible reconstruction because it is technically easier, secondary reconstruction may be rarely indicated.

Flap Geometry

Establishing the optimal position of the vascular pedicle and the skin paddle relative to the bone graft prior to surgery requires an understanding of the flap geometry. Because the right-sided donor site provides a very different vascular pedicle and skin paddle geometry than the left-sided donor site, it is important to predict the position of the defect and the donor vessels before choosing a donor side. In general, it is best to plate the bone graft on the surface that will least disrupt the vascular pedicle or periosteal blood supply. To optimize the vascularity of the graft, the plating surface often will dictate the orientation of the skin paddle and the vascular pedicle.

The Fibular Donor Site

When managing a right-side defect, if the contralateral donor site (left) is harvested, this will position the skin paddle intraorally and the vascular pedicle posterior. This geometry is commonly used for most routine composite defects involving the floor of mouth or tongue (**Fig. 2.1**).

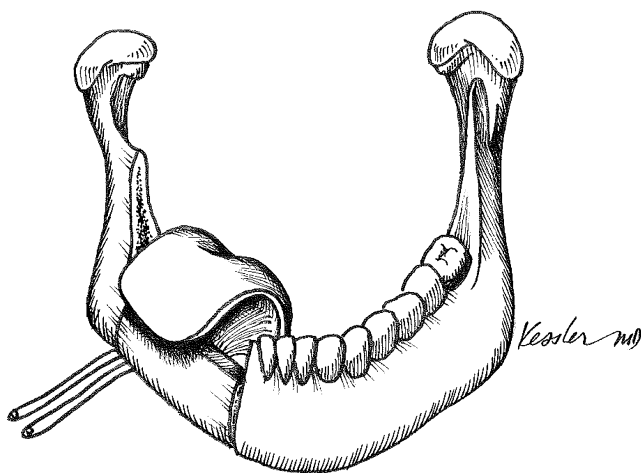


Fig. 2.1 The fibular free flap donor site. When the fibular donor site contralateral to the defect is harvested, the skin paddle will be positioned intraorally and the vascular pedicle will be positioned posteriorly. This geometry is commonly used for most routine composite defects involving the floor of mouth or tongue.

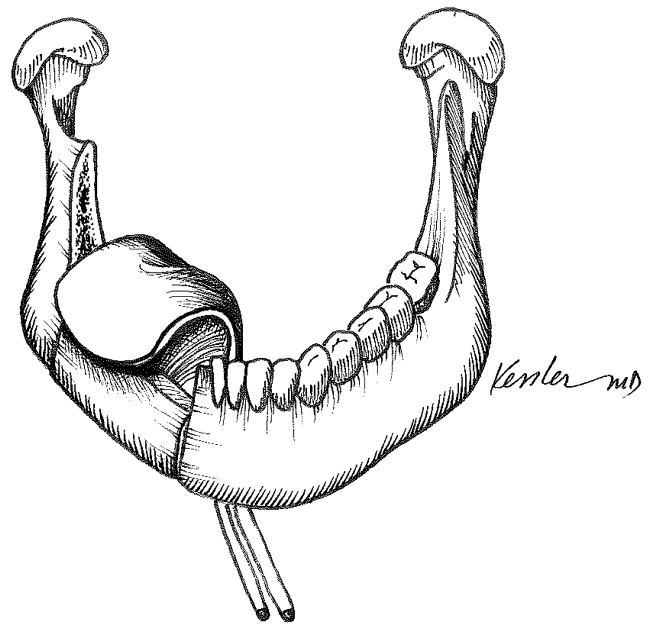


Fig. 2.2 The fibula free flap donor site. In situations where it is desirable to position the vascular pedicle anteriorly, the ipsilateral donor site will position the vascular pedicle anteriorly and the skin paddle intraorally.

In situations where it is desirable to position the vascular pedicle anteriorly, the ipsilateral donor site (right) will position the vascular pedicle anteriorly and the skin paddle intraorally. This geometry is less common but may be necessary when using donor vessels in the neck contralateral to the defect (**Fig. 2.2**).

When it is necessary to position the skin paddle externally and the vascular pedicle posteriorly, the ipsilateral donor site is used. This is common in defects of the external skin (**Fig. 2.3**).

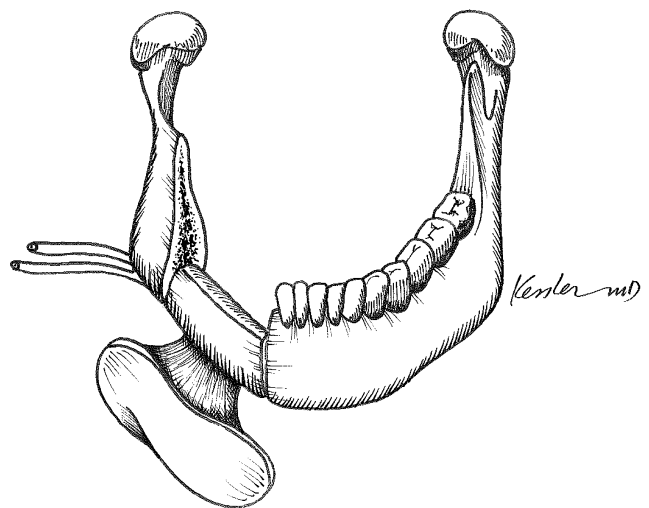


Fig. 2.3 The fibula free flap donor site. When it is necessary to position the skin paddle externally and the vascular pedicle posteriorly, the ipsilateral donor site is used. This is common in defects of the external skin.

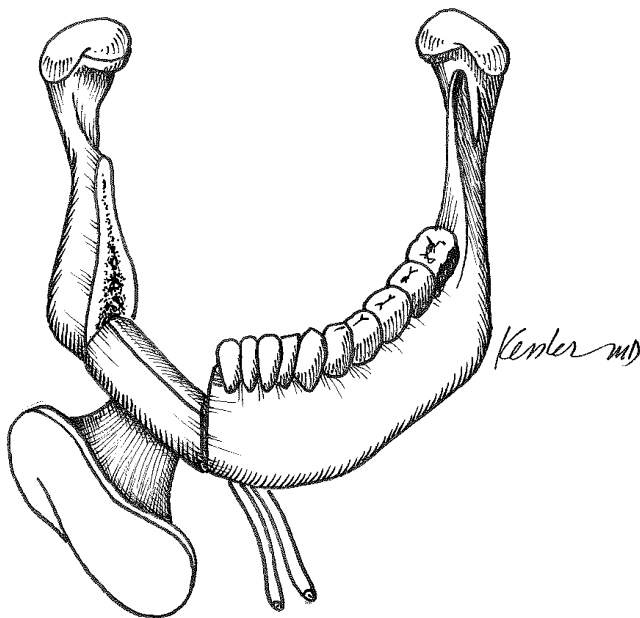


Fig. 2.4 The fibular free flap donor site. When the skin paddle is positioned externally and the vascular pedicle is anteriorly, the contralateral donor site is used.

When the skin paddle is positioned externally and the vascular pedicle is anterior, the contralateral donor site is used (**Fig. 2.4**).

The Iliac Donor Site

The tripartite design of the iliac crest-internal oblique flap lends itself to several orientations depending on whether a skin paddle is harvested with the internal oblique muscle. In

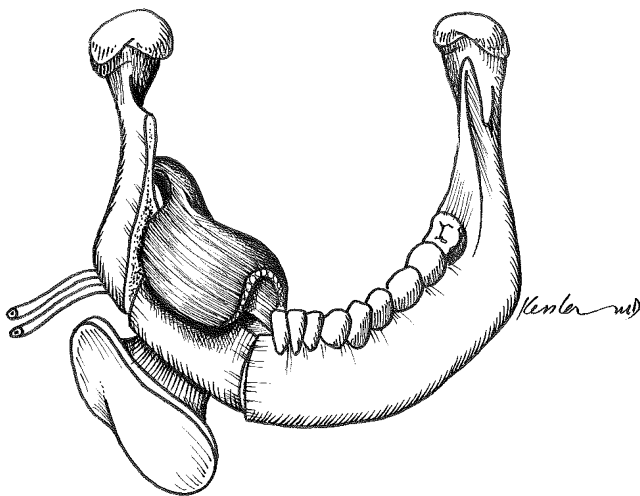


Fig. 2.5 The iliac crest donor site. When the donor site is ipsilateral to the defect, the pedicle will be oriented posteriorly and the internal oblique muscle will be oriented intraorally, with the skin oriented externally.

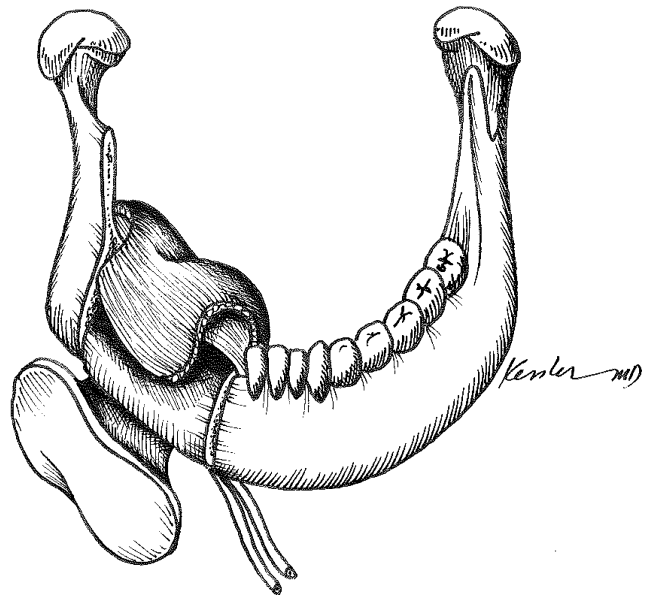


Fig. 2.6 The iliac crest donor site. When the donor site is contralateral to the defect, the pedicle will be oriented anteriorly and the internal oblique muscle will be oriented intraorally, with the skin oriented externally.

general, the muscle is usually oriented intraorally because it is more reliable. When the pedicle is oriented posteriorly, the ipsilateral donor site is harvested. This is the most common orientation because the vascular pedicle is usually positioned posteriorly (**Fig. 2.5**).

In those situations where the vascular pedicle needs to be oriented anteriorly, the contralateral donor site is harvested (**Fig. 2.6**).

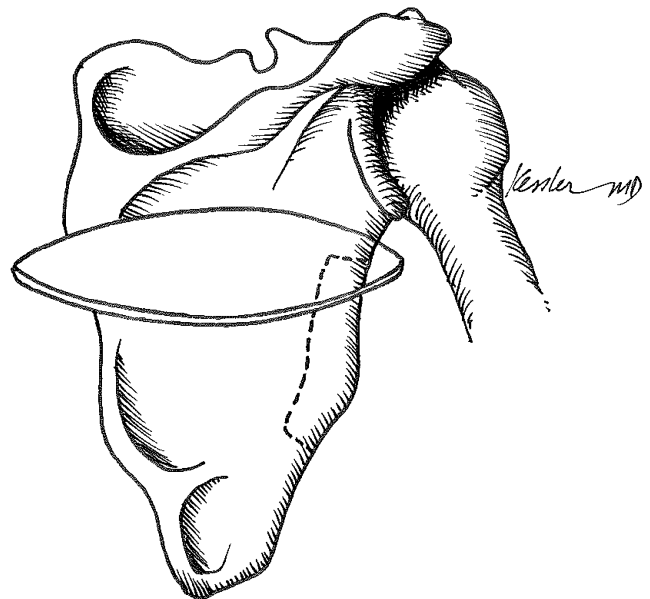


Fig. 2.7 The scapular skin paddle results in a flap orientation where the vascular pedicle is positioned posteriorly and the skin paddle lies perpendicular to the bone graft.

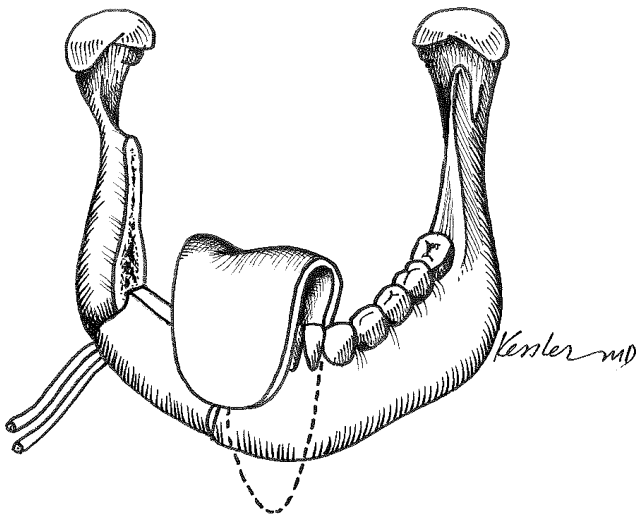


Fig. 2.8 The scapular skin paddle orientation is ideal for composite defects combined with an extensive hemiglossectomy or total glossectomy defect.

The Scapular Donor Site

The scapular donor site is the most versatile bone-containing free flap because the skin paddle has great versatility in its ability to rotate, and the skin paddle can be harvested from the scapular or parascapular sites.

The scapular skin paddle results in a flap orientation where the vascular pedicle is positioned posteriorly and the skin paddle lies perpendicular to the bone graft. This orientation is ideal for composite defects combined with an extensive hemiglossectomy or total glossectomy defect (Figs. 2.7 and 2.8).

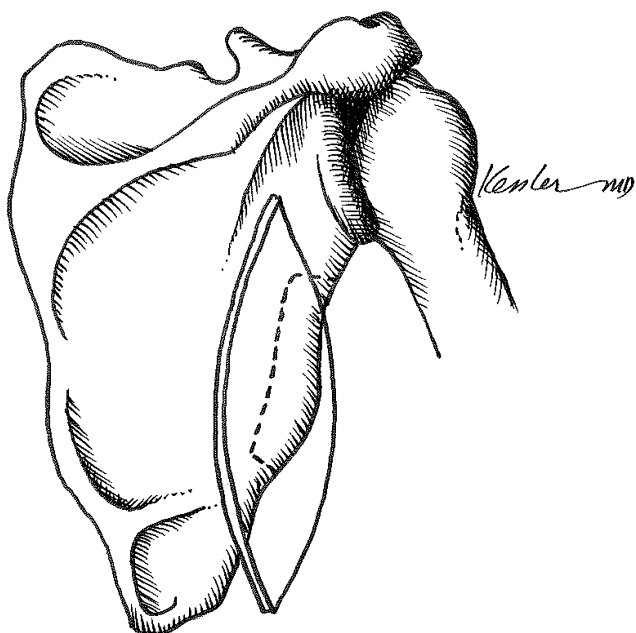


Fig. 2.9 The parascapular skin paddle results in a flap orientation where the vascular pedicle is positioned posteriorly and the skin paddle lies parallel to the bone graft.

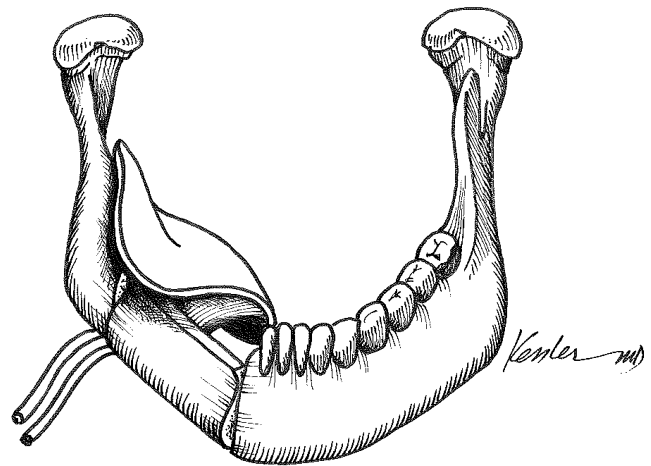


Fig. 2.10 This orientation is ideal for composite defects involving the floor of mouth or tongue.

The parascapular skin paddle results in a flap orientation where the vascular pedicle is positioned posteriorly and the skin paddle lies parallel to the bone graft. This orientation is ideal for composite defects involving the floor of mouth or tongue (Figs. 2.9 and 2.10).

◆ THE ANTERIOR OROMANDIBULAR DEFECT

With the exception of the rare isolated bony disease, defects of the anterior mandible nearly always involve the anterior floor of the mouth and in some cases the anterior tongue (Fig. 2.11). In rare cases, they may also involve the anterior lip or chin skin. Anterior mandible defects almost always require reconstruction because of the significant cosmetic and functional impact of this defect. Resection of the

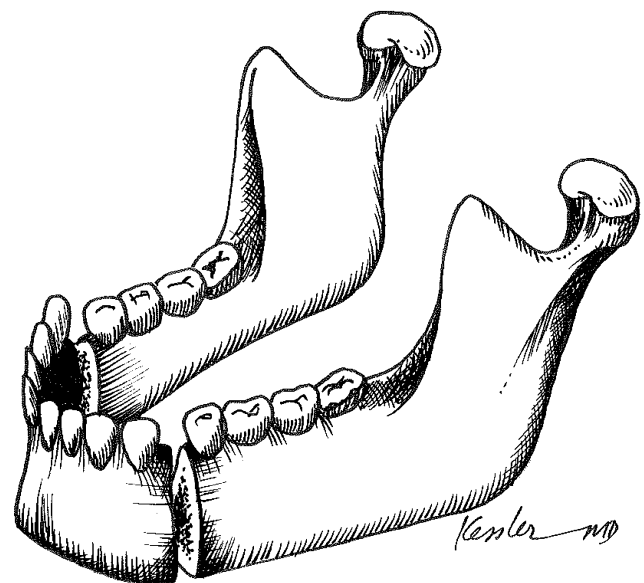


Fig. 2.11 The anterior mandibular defect.

anterior mandible leads to a characteristic cosmetic deformity often referred to as the “Andy Gump” deformity, named for the popular comic strip created by Sidney Smith in 1917 parodying a chinless character named Andy Gump. The characteristic chinless appearance is associated with a variety of cosmetic and functional deficits. Unlike other areas of the mandible, the anterior mandible plays an integral role in tongue position and laryngeal elevation. The genioglossus and geniohyoid muscles insert into the mandibular tubercle located on the medial aspect of the anterior mandible. When this insertion is compromised, the tongue will fall back into the pharynx, resulting in glossoptosis. When this dynamic is compromised, glossoptosis usually results in airway obstruction requiring a tracheostomy. Additionally, elevation of the hyoid and larynx that normally occurs during swallowing becomes compromised, resulting in aspiration. Consequently, patients with an Andy Gump deformity are commonly tracheostomy dependent and, in many cases, gastrostomy tube dependent.

Option for Management: Fibular Free Flap

Unless the mandibular defect is exceptionally small, most anterior mandible defects require free tissue transfer. This is usually because in addition to the bony defect, there is a concomitant soft tissue defect (**Fig. 2.12**). Although this can be accomplished with any of the three vascularized bone containing free flaps, the fibular donor site provides the optimal source of bone because multiple osteotomies can easily be performed to achieve the curvature of the anterior mandible without compromising the vascular integrity of the graft (**Fig. 2.13**). The fibular graft also provides a skin paddle that can be designed and rotated to address an anterior floor of mouth–tongue defect or a complex defect eroding through the anterior chin (**Fig. 2.14**). The most

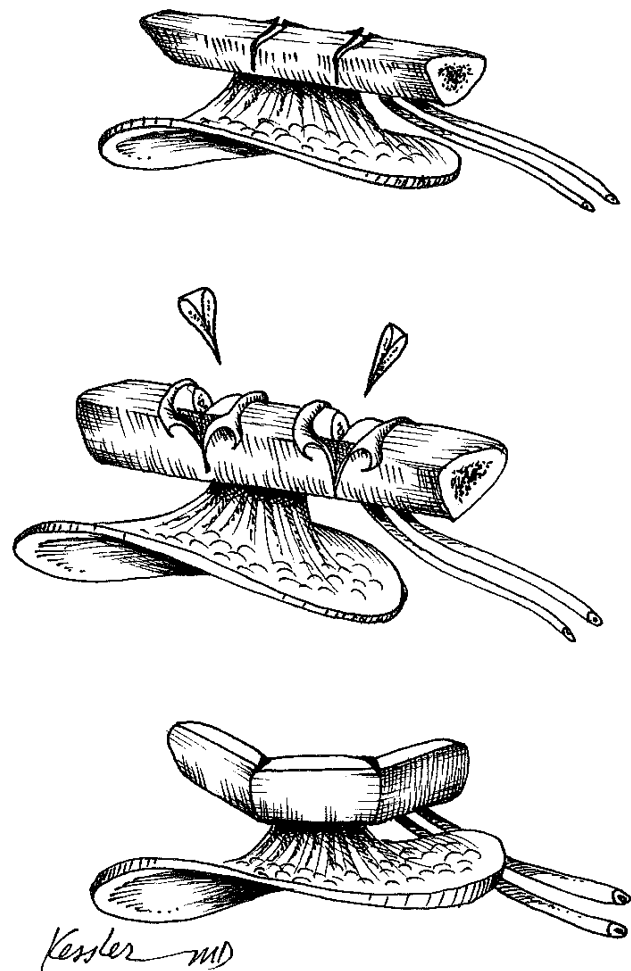


Fig. 2.13 Reconstruction with the fibular bone graft requires several closing osteotomies to achieve an acute bone graft arch.

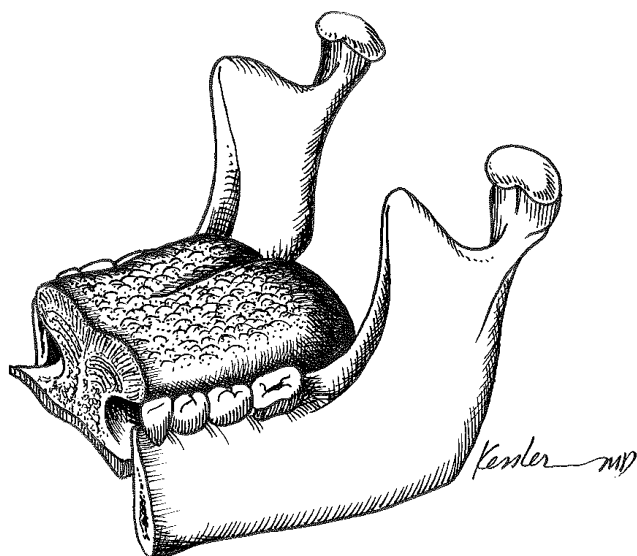


Fig. 2.12 The anterior mandibular defect is commonly associated with a floor-of-mouth and anterior tongue soft tissue defect.

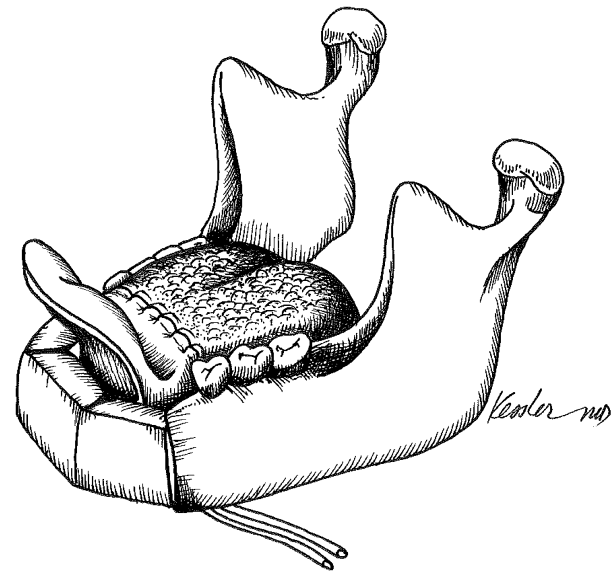


Fig. 2.14 The skin paddle can be used to reconstruct the floor of mouth and anterior tongue defect. It is important not to tether the anterior tongue and provide enough skin to allow for a sulcus in the floor of mouth. This helps maintain oral competence.

important aspect of the reconstruction lies in anchoring the genioglossus and the infrahyoid complex to the anterior mandible with a nonabsorbable suture to secure the tongue forward and elevate the larynx (**Fig. 2.15**). For this reason, we advocate using a single reconstruction plate to fixate the bone graft. The reconstruction plate provides the rigidity and fixation necessary to bear the stress of the anchoring sutures without disrupting the bony segments.

Surgical Technique and Considerations

- ◆ When possible, a reconstruction plate should be applied prior to tumor extirpation, especially in the dentate patient. This helps to maintain occlusion following the reconstruction. After fitting and securing the plate, it can be removed to perform the resection (**Fig. 2.16**).
- ◆ If a plate cannot be fitted prior to the extirpation because of a deforming lesion that precludes placement of the plate, an external fixation device can be used or the patient can be placed into internal maxillary fixation throughout the resection and fixation of the reconstruction plate.
- ◆ Once the defect has been established and the soft tissue margins have been evaluated, the plate can be reapplied and the donor vessels should be dissected and prepared.
- ◆ Typically, the skin paddle is designed in an elliptical fashion. If the defect involves the floor of mouth and tongue, the flap design is relatively straightforward. However, if there is a through-and-through defect, we like to identify two perforators and create two separate

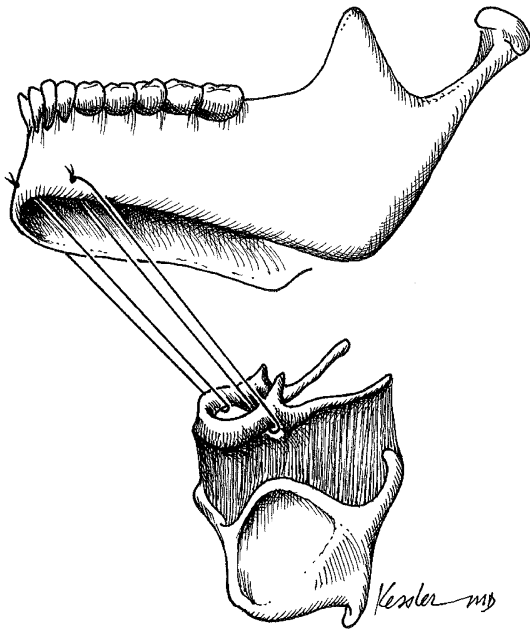


Fig. 2.15 The hyoid advancement is achieved by placing non absorbable sutures around the hyoid bone and through two holes in the inferior margin of the mandible. This helps to prevent aspiration following trisection of the suprahyoid muscle.

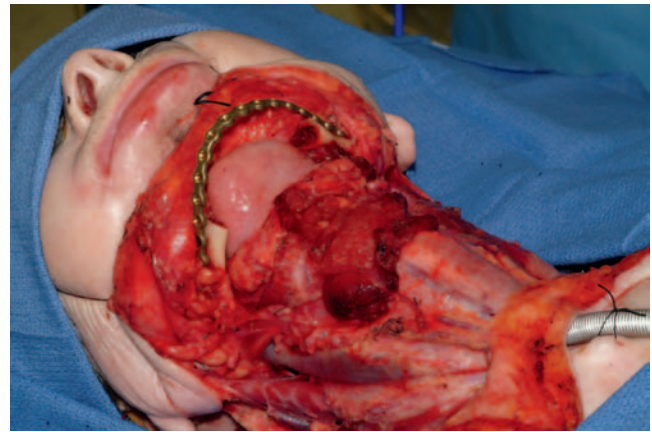


Fig. 2.16 Clinical case. The anterior mandibular defect is first managed by placing a titanium plate to reestablish occlusion.

skin paddles. Alternatively, a segment of skin can be de-epithelialized to establish two skin paddles.

- ◆ When using the fibular donor site, the vascular pedicle can be stripped and the excess bone can be trimmed (**Fig. 2.17**).
- ◆ The osteotomy sites should be marked and the periosteum can be dissected from the bone to provide access for the reciprocating saw.
- ◆ Closing osteotomies should be performed to achieve the appropriate curvature and bony arc.
- ◆ The bone graft can then be secured to the reconstruction plate.
- ◆ If there is a soft tissue defect, such as a floor-of-mouth defect, this aspect of the reconstruction can be addressed prior to the microvascular anastomosis.
- ◆ Following the microvascular anastomosis, a 0 or 2.0 Prolene suture can be placed around the hyoid bone and anchored to the midbody of the mandible to suspend the larynx and anchor the tongue. Suspending the larynx following an anterior mandibular reconstruction helps to improve laryngeal elevation

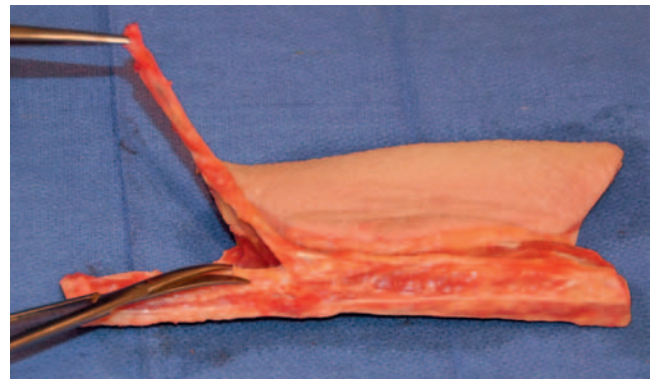


Fig. 2.17 To lengthen the vascular pedicle and achieve the appropriate amount of bone for reconstruction, the vascular pedicle can be dissected from the bone graft.

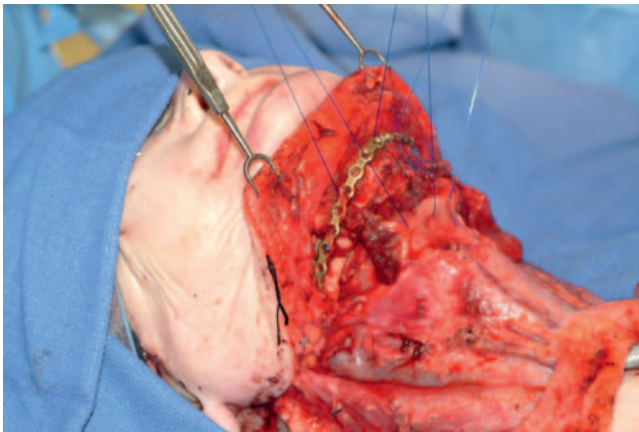


Fig. 2.18 After the osteotomies have been completed and the bone graft has been fixated, the hyoid should be elevated using hyoid advancement sutures. Heavy nonabsorbable sutures provide elevation of the larynx and protection against aspiration.

during swallowing and decreases the risk of aspiration (**Fig. 2.18**).

- ◆ When suspending the hyoid, exercise caution not to choke off the vascular pedicle as it exits the submental region of the neck.

Patient Selection and Perioperative Management

It is rare to encounter an isolated anterior mandibular defect without a significant soft tissue defect. Commonly

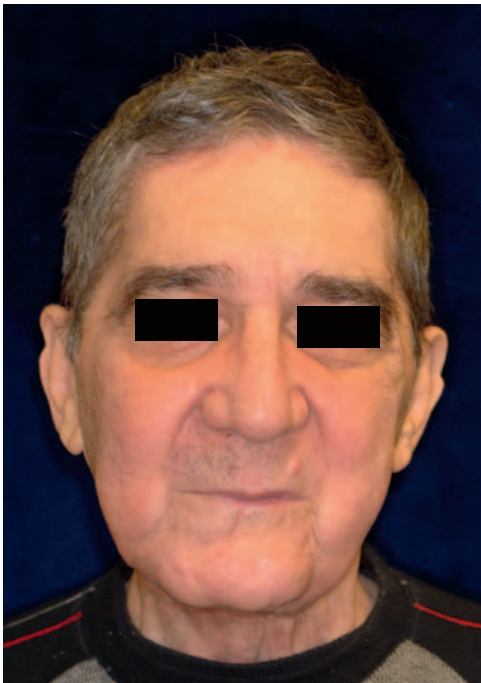


Fig. 2.19 Postoperatively, the contour and form of the mandible is preserved.



Fig. 2.20 The oral sulcus remains intact. This helps prevent oral incompetence.

the floor of mouth and ventral tongue will be involved. The fibular donor site is an excellent choice for reconstruction of this defect because the skin paddle is typically thin and pliable, lending itself to the contouring of the floor of mouth and anterior oral tongue. The cosmetic result and intraoral reconstruction are typically high quality with regard to facial symmetry and intraoral contouring (**Figs. 2.19** and **2.20**). Another option is the radial forearm–radial bone osteocutaneous donor site. This option provides a limited amount of bone that will not accommodate osseointegrated implants, but provides an excellent source of skin for reconstruction of the anterior oral cavity anatomy. An optimal reconstruction requires that the oral tongue is not tethered because this will impede articulation and manipulation of the food bolus.

Postoperatively, the patient should remain nil per os (NPO) for 7 days if not irradiated; however, if the patient is radiated, we recommend NPO for 10 to 14 days depending on the condition of the patient's tissue and nutritional status.

◆ THE LATERAL OROMANDIBULAR DEFECT

The reconstructive options for the lateral mandibular defect have been the focus of some controversy in the past. Although free tissue transfer with a vascularized bone-containing free flap has become the standard of care, small defects of the lateral mandible can be managed without a bony restoration. This is often referred to as the “swinging mandible” because the two free segments of the mandible essentially swing when they are not in continuity. The swinging mandible leads to migration of the free bone medially as a result of unopposed muscular contracture. This often leads to a debilitating cross-bite deformity that can result in TMJ pain, impaired mastication, and a significant cosmetic deformity. There is a population of patients who tolerate the

unreconstructed defect surprisingly well, although their oral diet is often restricted to soft foods.

There are several options for reconstruction of the lateral mandibular defect; however, in the final analysis, the patient's ability to tolerate general anesthesia will often predict the most plausible options for reconstruction. A reconstruction plate may be suitable for the frail patient with no significant soft tissue defect, whereas a reconstruction plate with a pectoralis flap skin paddle may be required in the same patient when the soft tissue defect is substantial. In contrast, a healthy patient with expectations of osseointegrated implant oral–dental rehabilitation may benefit from an osseocutaneous free flap reconstruction. Matching the patient with the optimal reconstructive technique requires a global evaluation of the patient's comorbidities and the inherent donor-site morbidity.

Option for Management: Reconstruction Plate

The reconstruction plate was introduced in the early 1980s, when it was applied to the lateral defect in an effort to stabilize the two free bone segments and avert the pain and deformity associated with the cross-bite deformity. Although this technique became exceptionally popular, a variety of complications including plate fracture, plate exposure, and infection were described.^{19,20} Several reports have subsequently been published citing the advantages of vascularized bone reconstruction.^{21,22} Chepeha et al²³ recently explored the question of when a bridging reconstruction plate combined with a soft tissue revascularized flap is appropriate for a lateral mandibular defect. They found that plate fracture is a limiting factor; however, plate exposure could be limited if a bulky soft tissue flap is used to cover the plate. Arden et al²⁰ retrospectively reviewed 31 patients to evaluate the relationship between soft tissue volume loss and bone resection length following lateral segmental mandibulectomy with plate reconstruction, and to determine the complication rates. They found complications occurred in 45% of patients, which included plate exposure (29%), loosened screws requiring hardware removal (29%), fistula (14%), local wound infection (14%), osteomyelitis (7%), and plate fracture (7%), and that the average time to complication was 7.7 months. Most importantly, complication rates were 81% for bone defects greater than 5.0 cm. Head et al²⁴ also reviewed their experience comparing the efficacy of vascularized bone grafts and bridging mandibular reconstruction plates for restoration of mandibular continuity in patients who undergo free flap reconstruction after segmental mandibulectomy. They found that vascular bone reconstruction was preferred; in select cases, however, the bridging plate provided an acceptable option with minimal complications.

Although the disadvantages of plate reconstruction are well recognized, in certain clinical situations a prolonged surgical procedure may not be indicated. In patients who are medically tenuous or in palliative situations, a reconstruction plate provides an expeditious approach that may suffice. Although this approach may reduce the operative time, in most cases, typically, the plate will either fracture or extrude from the skin within 2 years.^{24,25} This is especially common

in patients who require external beam radiotherapy or who have been radiated in the past.²⁰ Because radiotherapy causes microvascular disease that inhibits tissue healing, wound break down is common. While Chepeha et al²³ suggested the placement of a bulky, well-vascularized soft tissue flap placed over the lateral aspect of the plate to help to facilitate healing, this approach will not prevent plate fracture.²⁰

Surgical Technique and Considerations

- ◆ When using a reconstruction plate without a vascularized bone graft, a 2.4-mm plate is ideal because it is more likely to tolerate stress and resist fracture than a 2.0-mm plate.
- ◆ Because plates have the tendency to erode through the skin, interposing muscle between the reconstruction plate and the skin can help to delay this complication.
- ◆ When a pectoralis flap skin paddle is used to reconstruct an intraoral defect, the muscle can be placed over the reconstruction plate; however, if the overlying skin closure is tight, it may compromise the blood supply to the skin paddle.

Patient Selection and Perioperative Management

Patient selection for mandibular plate reconstruction is crucial. In general, patients selected for this type of reconstruction are limited to (1) those patients who are medically unfit to tolerate a free tissue reconstruction; (2) patients who choose to undergo palliative surgery and will not necessarily require a long-term durable reconstruction; and (3) patients who make the conscious decision not to undergo free tissue transfer. Relative contraindications to plate reconstruction include those patients with mandibular defects greater than 5 cm and patients who anticipate oral dental rehabilitation.

Postoperatively, nonradiated patients should remain NPO for 7 days, whereas radiated patients remain on nasogastric feeds for 10 to 14 days to allow the intraoral wound to heal.

Option for Management: Nonvascularized Free Bone Graft

A variety of nonvascularized bone grafts have been used for mandibular reconstruction, including autogenous and allogeneic grafts. Autogenous bone grafts are patient-derived, usually from the hip or the calvaria. These grafts provide a source of viable osteoblastic cells as well as pluripotential mesenchymal cells that can differentiate into osteoblastic cells in the presence of bone morphogenetic proteins. Autogenous bone grafts can be harvested as cancellous, cortical, or corticocancellous grafts. The optimal form of the graft is predicated on the type of defect to be reconstructed. Cancellous bone grafts are composed of medullary bone and marrow and contain the highest proportion of viable donor cells. The particulate structure and large surface area facilitates the revascularization process. In contrast, cortical

grafts are composed primarily of osteocytes, which rarely survive transplantation. Corticocancellous grafts consist of a piece of cortical bone with its underlying cancellous portion. This type of graft provides not only viable osteoblastic cells but also the structural integrity necessary to bridge discontinuity defects. Large corticocancellous bone blocks are slow to revascularize and therefore are prone to resorption.

Although corticocancellous bone grafts can be used for 1- and 2-cm defects, particulate cancellous bone and marrow supported with a titanium mesh is one of the most popular techniques used for mandibular reconstruction. The particulate bone and marrow provides a source of viable material for bone healing, and the titanium mesh acts as an infrastructure. Although still used, this technique requires a favorable recipient bed, that is, a bed whose milieu promotes graft healing. This is achieved when the recipient bed is well vascularized and unexposed to bacterial contamination. Bone graft healing is unique in that it requires that new bone be formed. Graft healing, or incorporation, is dependent on the number of osteoblasts contained within the bone graft and the density of vessels that provide the nutrients needed to ensure graft survival. Any process that limits either the cell viability or the vascularity of the recipient bed will hinder graft incorporation, and the rate of graft breakdown can be excessively high. Radiotherapy greatly affects the quality of the soft tissues by causing hypocellularity, hypovascularity, and hypoxia of the recipient bed. In contrast, techniques such as hyperbaric oxygen create a marked oxygen tension gradient between the hypoxic radiated bed and the surrounding normal tissues, resulting in osteoangiogenesis. The increase in oxygen tension induces new blood vessel growth that provides the elements required to support the incorporation of a free bone graft. When hyperbaric oxygen is not available, the quality of the soft tissues can be improved by the transfer of well-vascularized soft tissue.

Arguably, bacterial contamination is the most significant deterrent to free bone graft healing. It is for this reason that a mucosal defect is a contraindication to nonvascularized bone graft reconstruction. The high concentration of bacteria within the saliva prevents vascular ingrowth and new bone formation. To optimize the outcome, a nonvascularized bone graft should be reserved for defects of less than 3 cm and defects that do not violate the oral mucosa.

Surgical Technique and Considerations

- ◆ For defects that are 1 to 2 cm, a single iliac corticocancellous bone graft may be sufficient. The graft should be fixed with a 2.0- or 2.4-cm reconstruction plate.
- ◆ For larger defects managed with particulate cancellous bone and a titanium crib, the titanium tray should be prefitted prior to the resection to preserve dental occlusion.
- ◆ Although cancellous bone and marrow can be harvested from any of several donor sites, the posterior iliac crest is ideal. This donor site supplies a rich source of dense osteogenic material and is associated with minimal morbidity.

- ◆ After the titanium mesh has been filled with corticocancellous bone, immobility and a stress-free environment for 6 to 8 weeks is essential.

Patient Selection and Perioperative Management

For defects that are 1 to 2 cm, a single iliac corticocancellous bone graft may be sufficient; however, for larger defects, particulate cancellous bone with marrow and titanium mesh is a more reliable approach. With either technique, an intraoral communication creates an unfavorable recipient bed, and in such cases one should consider staging the mandible reconstruction after the intraoral mucosal defect has healed.

Prior radiation exposure represents a relative contraindication because it impedes the vascularity of the recipient site, and this patient population should be approached with caution.

Postoperative management is focused on rigid fixation and preventing salivary contamination of the graft. A well-fitted titanium mesh tray will usually provide adequate fixation. Immobility and a stress-free environment for 6 to 8 weeks are essential to promote bone formation.

Option for Management: Fibular Free Flap

The lateral mandibular defect includes the isolated mandibular defect or a composite defect that may include any combination of the alveolar mucosa, oral tongue, or the buccal mucosa. During the resection, we advocate performing a coronoidectomy at the time of the composite resection to prevent postoperative trismus (**Fig. 2.21**). The optimal donor site is predicated on the following three factors: (1) the defect complexity, (2) the body habitus of the patient, and (3) the patient comorbidities.

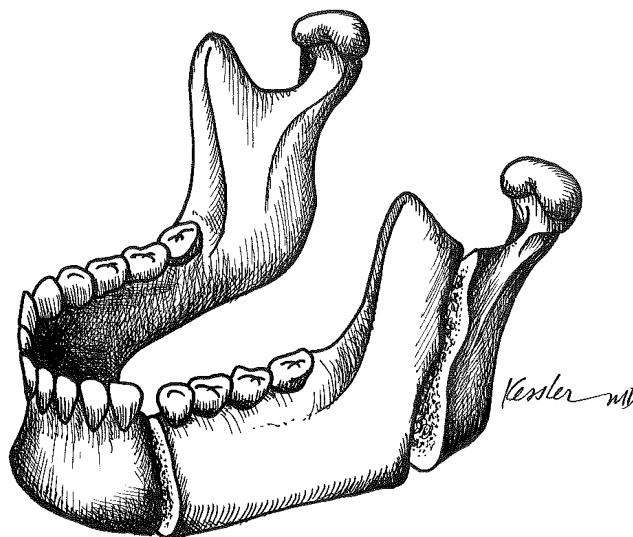


Fig. 2.21 The lateral mandibular defect with coronoidectomy.

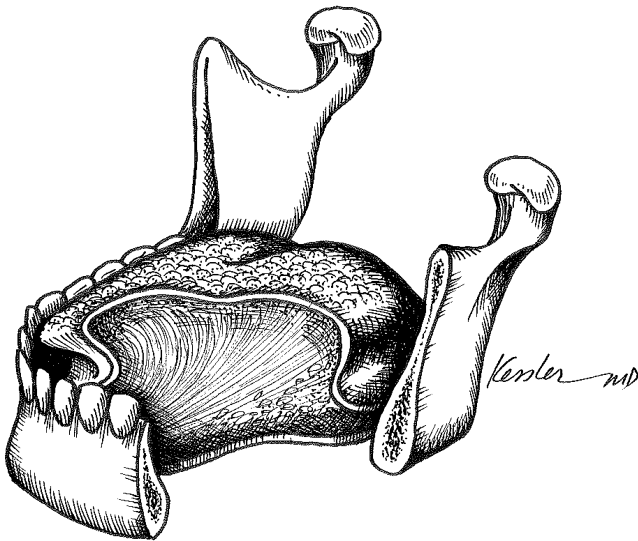


Fig. 2.22 The lateral mandibular defect is often associated with a floor-of-mouth and partial glossectomy defect.

The defect complexity refers to the areas of the oral cavity involved in the defect. Examples include an isolated bony defect, a bone and oral mucosal defect, or a through-and-through defect involving the mandible, oral mucosal, and external skin. The majority of defects involve a combination of the mandible and the adjacent floor of mouth or oral tongue (**Fig. 2.22**). An isolated bony defect can be managed with any of the major bone-containing free flap donor sites, although some may argue that the bone stock of the fibula and the iliac crest are more capable of accommodating osseointegrated implants; in the adult patient, there is no

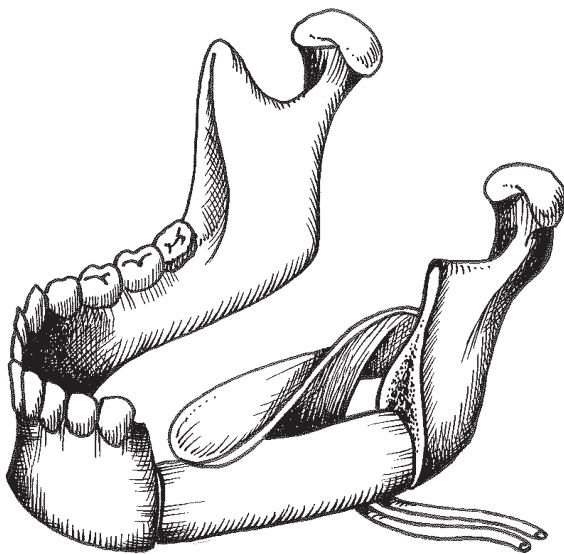
significant difference. The advantages of the fibular donor site include the ability to perform a two-team harvest and the general diversity of the fibular donor site.

The more complex defects require a skin paddle that is pliable enough to re-create the natural sulcus of the floor of mouth and not tether the mobility of the oral tongue (**Fig. 2.23**). Both the fibula and the scapular donor sites are excellent options. The best option is often related to the patient's body habitus and the patient's comorbidities. Although the scapular donor site provides the two separate vascularized bone grafts and a variety of skin and muscle paddles that are ideal for the complex defect, the skin paddle in a heavy-set patient may be too bulky to achieve the fine contouring of the oral cavity. In contrast, a patient with severe peripheral vascular disease may not have the appropriate distal three-vessel flow to accommodate a fibular graft. These examples highlight the many factors that need consideration when approaching complex oral cavity reconstruction.

Surgical Technique and Considerations

- ◆ When managing a right-sided defect, the contralateral donor site (left) will position the skin paddle intraorally and the vascular pedicle will emerge posteriorly (**Fig. 2.24**).
- ◆ When this orientation is used, the plate can be applied to the periosteal surface of the bone graft without tethering the skin perforators.
- ◆ The fibular skin paddle is typically well positioned for the simple lateral oral tongue, floor of mouth, or lateral pharyngeal wall defect. The skin paddle should be created with enough redundancy to provide for a sulcus

A



B

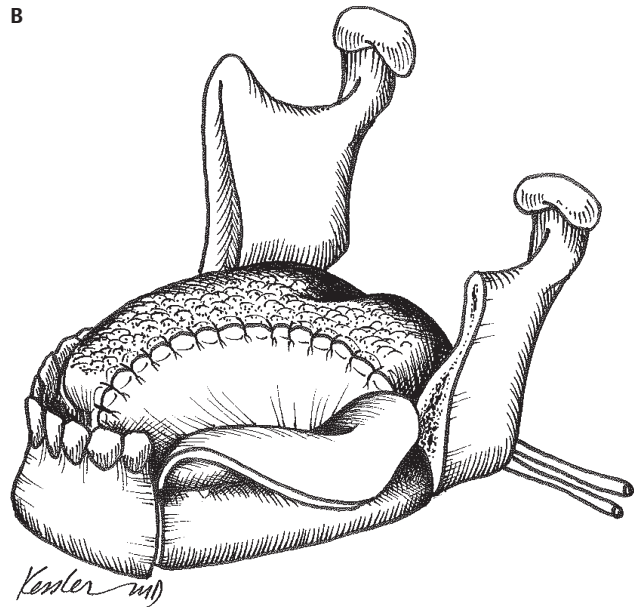


Fig. 2.23 The fibular donor site provides an excellent source of bone and soft tissue to reconstruct this defect. **(A)** The orientation of the flap and bone graft is shown. **(B)** The soft tissue reconstruction is shown.



Fig. 2.24 Clinical case. The lateral mandibular defect with floor-of-mouth and partial glossectomy.

in the floor of mouth and enough laxity not to tether the oral tongue (**Figs. 2.25** and **2.26**).

- ◆ In cases of the vessel-depleted neck where the fibular vessels need to be directed to the opposite neck, the donor site ipsilateral to the defect (i.e., right-sided defect and right-sided donor site) can be used to position the vascular pedicle anteriorly and provide the geometry necessary to reach the opposite neck.
- ◆ An osseointegrated implant can be placed primarily or secondarily. When placed primarily, we prefer to place

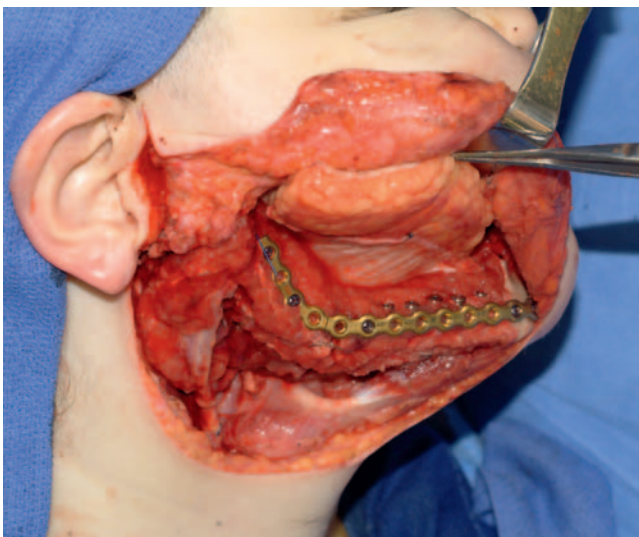


Fig. 2.25 Fibular free flap reconstruction with primary osseointegrated implants.

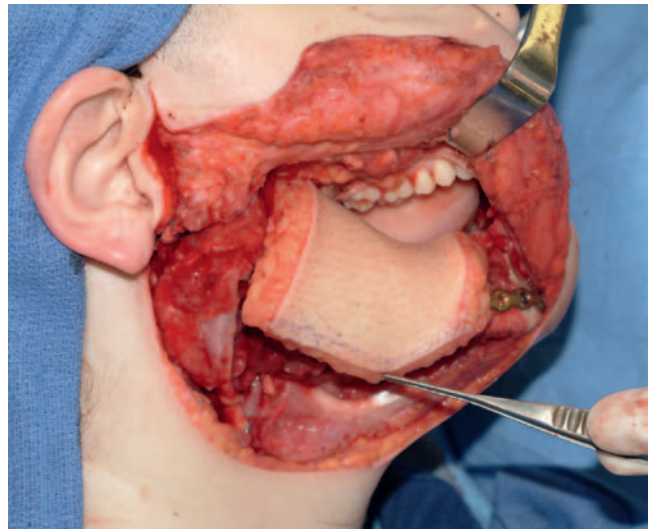


Fig. 2.26 The contralateral donor site was harvested so that the skin paddle can be positioned intraorally and the vascular pedicle is oriented posteriorly.

it after the bone has been position, fixed, and revascularized (**Fig. 2.27**).

Patient Selection and Perioperative Management

The fibular donor site is an excellent first-line donor site option for the lateral mandibular defect; however, if the lower extremity vessels are not favorable or the patient is not a good candidate for a fibular harvest, the scapular or iliac crest can be considered. Following a fibular harvest, patients require a term of immobility that can raise the risk



Fig. 2.27 Computed tomography scan demonstrating the position of the dental implants.



Fig. 2.28 Postoperative result demonstrating excellent mandibular contour.

of deep venous thrombosis. In patients with a high risk of venous thrombosis, the alternative donor sites should be considered.

When the fibular donor site is used, we recommend a posterior lower extremity splint for 7 days followed by range-of-motion and strength therapy with partial weight



Fig. 2.29 Postoperative result, three-quarter view.



Fig. 2.30 Intraoral view following placement of osseointegrated implants and implant-borne dentures.

bearing at 2 weeks and full weight bearing at 3 to 4 weeks. We allow 6 weeks for bone healing before the patient's diet is advanced to a soft diet. The fibular reconstruction is well tolerated, particularly in the younger population. It provides sufficient bone to preserve facial skeletal symmetry (**Figs. 2.28** and **2.29**) and retention of osseointegrated implants for implant-borne dental restoration (**Fig. 2.30**).

◆ THE LATERAL OROMANDIBULAR DEFECT WITH THROUGH-AND-THROUGH SKIN DEFECT

Unlike the simple lateral mandibular defect, the through-and-through defect requires intraoral lining, a vascularized bone graft, and an external skin paddle. There are a variety of options to manage this type of defect, including the fibular donor site designed with two skin paddles, the scapular donor site, or a combination of two flaps. A variety of factors, including donor-site availability, the aesthetic goals of the patient, and the involvement of the facial musculature, will dictate the optimal approach to this daunting defect.

The fibular donor site can be applied to the through-and-through defect if two vascular perforators are defined or a bridge of intervening skin is de-epithelialized. The scapular donor site provides an excellent source of multiple skin paddles and two vascularized bone grafts that is ideal for complex defects of the oral cavity. Finally, in select situations, a combination of flaps can be used, such as the fibular and the posterior scalping flap or cervicofacial advancement flap.

Option for Management: Scapular Free Flap

Often referred to as the “subscapular system of flaps” because of the wide variety of flaps that can be harvested based on the subscapular vessels, the versatility of the scapular free



Fig. 2.31 Intraoperative photo demonstrating an infiltrating lesion that will result in a through-and-through defect involving the skin, mandible, floor of mouth, and oral tongue.

flap has been well documented. This donor site is unique because it provides a variety of options including two vascularized bone flaps (the lateral border of scapula and the scapular tip), two different skin paddle designs (the parascapular and the scapular), and the ability to harvest the latissimus dorsi myocutaneous flap. This diversity lends itself to complex reconstruction such as the through-and-through oromandibular defect (**Fig. 2.31**).

The through-and-through oromandibular defect can be managed using the scapular skin paddle for intraoral lining and cheek reconstruction, or the latissimus dorsi can be harvested on the thoracodorsal artery and vein and used for external lining (**Fig. 2.32**). When the latissimus dorsi is used for the cheek reconstruction, a latissimus can be harvested with a skin paddle, or when the skin paddle is excessively

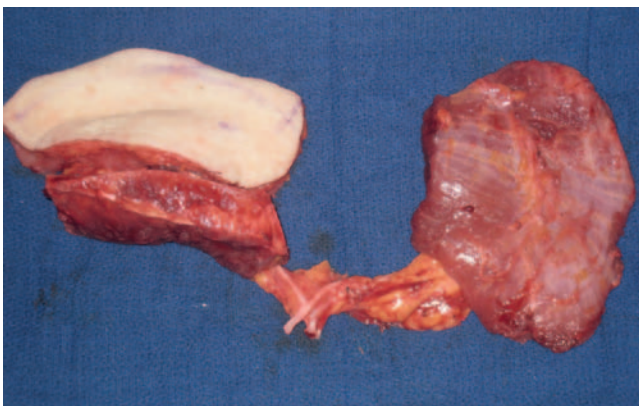


Fig. 2.32 The scapular free flap with latissimus muscle.

bulky, the muscle can be harvested and a skin graft can be used. The advantage of the muscle with the skin graft is that the muscle and skin graft tend to contract, resulting in a less significant skin defect (**Fig. 2.33**). Further, when the facial musculature is involved in the primary resection, the latissimus can be reinnervated via the thoracodorsal nerve and oriented to provide volitional facial reanimation.

Surgical Technique and Considerations

- ◆ In most cases, it is desirable to orient the flap so that the vascular pedicle is directed posterior and the medial aspect of the scapular bone graft is plated. To achieve this, the ipsilateral donor site is optimal.
- ◆ Depending on the extent of the oral cavity defect, it is preferable to begin the reconstruction by fixating the bone using a reconstruction plate to achieve the appropriate occlusion. Then release the anterior plate fixation to distract the mandibular reconstruction, thereby gaining access to the oral cavity to perform the intraoral reconstruction. By releasing the anterior fixation, access to the oral cavity is improved, making the intraoral reconstruction easier.
- ◆ The skin paddle is ideal for relining the oral cavity. However, in some patients the subcutaneous fat can make for a bulky flap that prohibits a reliable closure. In such cases, the thoracodorsal fascia can be used in lieu of the skin. This fascia provides a watertight closure but will require a period of re-epithelialization. Although useful in select cases, this technique can lead to contraction that may tether the tongue.



Fig. 2.33 Intraoperative view. The skin paddle is used to reconstruct the oral tongue, the bone graft is oriented into the mandibular defect, and the latissimus muscle with a skin graft will be used to address the cheek defect.



Fig. 2.34 Two week postoperatively, the skin graft has healed over the latissimus muscle.

- ◆ Once the intraoral reconstruction is complete, the mandible can be fixated and the latissimus skin paddle or latissimus muscle with a skin graft can be placed into the external skin defect (**Fig. 2.34**).
- ◆ When the facial musculature has been resected, the latissimus can be reinnervated via the thoracodorsal nerve and oriented to provide volitional facial reanimation.

Patient Selection and Perioperative Management

If the latissimus muscle is used with a skin graft, postoperatively the muscle and skin graft will contract (**Fig. 2.35**). This will allow for future revision and serial skin graft excision (**Fig. 2.36**). The scapular donor site has its distinct advantages and disadvantages. Although this donor site provides an unparalleled variety of soft and hard tissue flaps, it requires that the patient be placed in the decubitus position for the harvest, making a two-team approach impractical. The donor vessels are typically unaffected by peripheral vascular disease, which is common in the lower extremities, and this donor site avoids the immobility that is required for the fibular donor site. This allows patients to begin ambulation early in their convalescence.

The donor site can be bulky in certain patients with a high body mass index (BMI), and this can make the intraoral reconstruction difficult. Although the thoracodorsal fascia can be used, the contraction associated with re-epithelialization can be unpredictable and may tether the tongue and impact speech and swallowing. Other donor sites and combinations of sites can be used to manage the through-and-through defect; however, few are as reliable as the



Fig. 2.35 Ten week postoperatively, the latissimus muscle has atrophied and the skin graft has contracted. The patient presents for adjacent tissue advancement and excision of the skin graft. This technique is helpful in minimizing the cheek defect.

scapular donor site for the complex through-and-through defect.

Postoperatively, the patient is placed into a shoulder splint to allow for donor-site healing. By postoperative day 5 the splint is withdrawn and range-of-motion exercises are instituted by a physical therapist. Strength therapy is added to the therapy on days 10 to 14.



Fig. 2.36 Three months postoperatively, the patient has achieved an excellent cosmetic and functional result.

Option for Management: Fibular Free Flap and Posterior Scalping Flap

The major drawback of free flap reconstruction of the cheek defect is the poor color and texture match that donor-site skin provides. The submental island and cervicofacial and posterior scalping flaps have been cited as regional flaps that provide skin that is a relatively good color and texture match. When the through-and-through defect involves the cheek and aesthetics are a significant concern, a free flap can be used to address the oral cavity defect, and a local-regional flap can be used to address the cheek defect. Although the cervicofacial and submental island flap provide the simplest approach, they are limited to moderate defects of the cheek. The posterior scalping flap is an older technique first described as an extension of the nape of neck flap. Its advantages are the excellent color and texture match with the cheek skin; however, there are significant disadvantages, including that it is a staged procedure requiring a compliant patient. When the mandible is not involved, and facial reanimation is desired, the posterior scalping flap can be combined with the gracilis flap to achieve volitional facial movement.

Surgical Technique and Considerations

- ◆ Once the oral cavity and mandibular defect have been addressed, the posterior scalping flap can be raised. It is preferable to raise the posterior scalping flap early in the procedure to provide time to confirm that the perfusion to the distal flap is reliable.
- ◆ In secondary reconstruction, the posterior scalping flap can be staged to improve reliability, or a tissue expander can also be used to increase the skin paddle area and facilitate donor-site closure.
- ◆ The flap should be designed with laxity as it spans the defect. Any tension will compromise vascular perfusion and impede healing.
- ◆ Deep absorbable sutures should be placed to relieve the tension of the skin closure.

Patient Selection and Perioperative Management

The superficial temporal arterial system must be intact to use this technique. In secondary reconstruction the flap can be staged or a tissue expander can be used to increase the flap area. One of the most important aspects of patient selection is identifying a compliant patient. Any time a staged reconstruction is considered, it is essential that the patient be informed of the patience and understanding that are necessary to achieve the final result. Careful preoperative consultation will avoid postoperative discontent.

Postoperatively, the donor site is covered with petroleum jelly-impregnated gauze. In some cases a skin graft can be used to resurface the lower aspect of the donor site. After 2 to 3 weeks, the flap can be transected and the bridging posterior scalp tissue can be returned to the harvest site of the posterior scalp. If the cheek scars at the flap-cheek interface,

dermabrasion or CO₂ laser therapy can be used to improve the cosmetic result.

◆ THE CONDYLAR DEFECT: THE SHORT SEGMENT CONDYLAR DEFECT

The condylar defect may be limited to a small portion of the condylar neck and condylar head, or it may include the entire ascending ramus (**Fig. 2.37**). Tumors of the condyle often result in an isolated defect that can be managed without reconstruction, a prosthetic implant, or an autogenous graft. Failure to reconstruct the condyle can be well tolerated but it may also lead to shifting of the mandible, malocclusion, and chronic pain. For these reasons, most surgeons advocate primary reconstruction when possible. Prosthetic reconstruction has been the subject of much debate, largely because of reports of cranial base erosion. It has been our experience that although prosthetic condylar reconstruction offers an excellent short-term option, long-term results are less encouraging. We have experienced lateral extrusion and cranial base erosion of the implant. This is especially problematic in patients treated with postoperative external beam radiotherapy. However, the rib graft provides an excellent option for reconstruction in select cases (**Figs. 2.38 and 2.39**).

Option for Management: Rib Graft

In the author's experience, short-segment condylar defects respond well to rib graft reconstruction. The graft can be harvested with a segment of bone and distal cartilage that can be sculpted to re-create the native condylar head. Because the graft is not vascularized, longer segment grafts may resorb, especially in a radiated field.

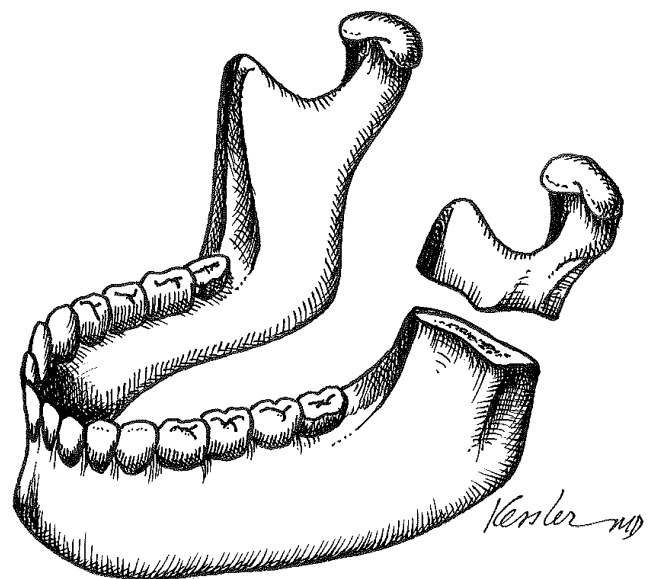


Fig. 2.37 The short segment condylar defect.

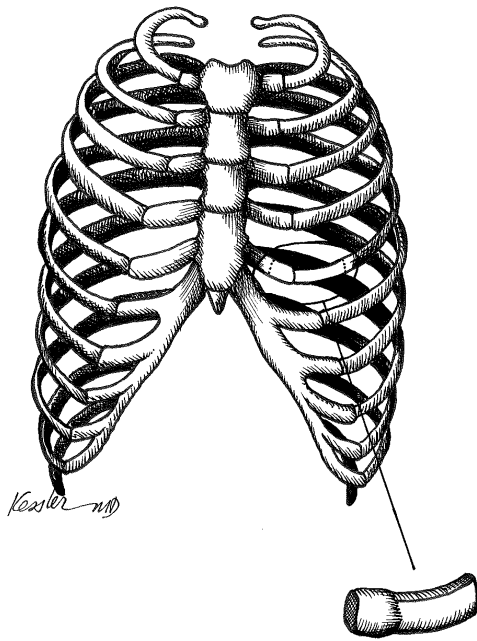


Fig. 2.38 The rib graft provides an excellent source of hard tissue for short segment condylar reconstruction in the nonradiated field. The graft has both a bony component and a cartilage component that can be used in the condylar fossa.

Surgical Technique and Considerations

- ◆ During the course of the resection, if the facial nerve is preserved, we prefer to dissect out the main trunk to prevent facial nerve injury (**Fig. 2.40**).
- ◆ The rib graft should be harvested from the medial aspect of the lower four ribs. This will provide a graft that is

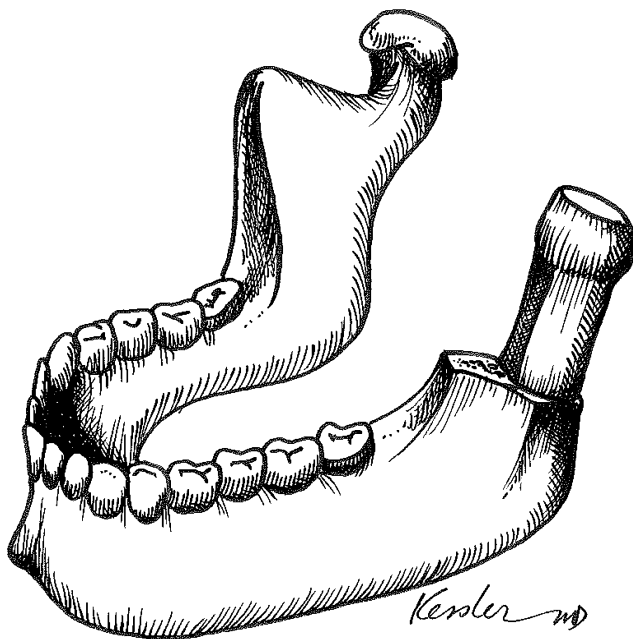


Fig. 2.39 The rib graft is positioned and fixated so that the cartilage acts as a neo-joint.

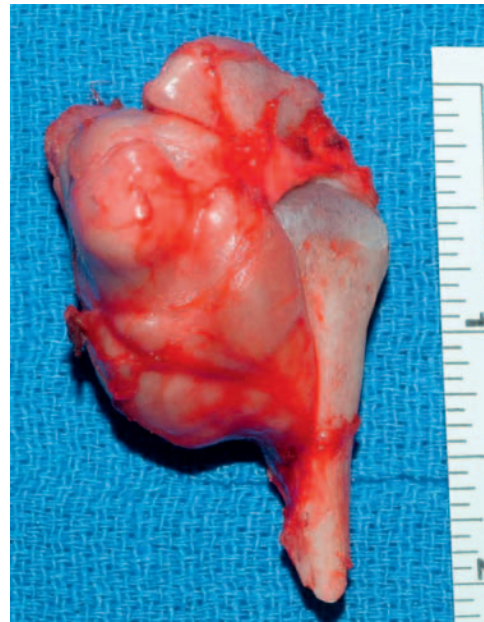


Fig. 2.40 Clinical case. Resection of the condyle for a cartilaginous tumor of the condyle.

composed of bone and cartilage to reconstruct the condylar neck and head, respectively (**Fig. 2.41**).

- ◆ The cartilage can be sculpted to fit into the glenoid fossa.
- ◆ The rib is then cut to the appropriate length and fixed to the mandible using 2.0-mm miniplates.



Fig. 2.41 A segment of the rib is harvested. The distal aspect of the graft is cartilage, whereas the proximal region is bone.

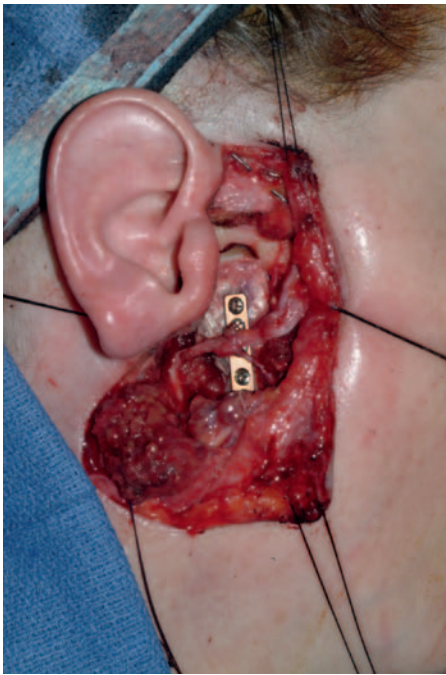


Fig. 2.42 A 2.0-cm reconstruction plate is used to fix the rib graft. The facial nerve is draped over the graft.

- ◆ To guide the condylar head during healing and while a pseudarthrosis forms, we pass a 25-gauge wire through the rib cartilage and secure it to the glenoid fossa (**Figs. 2.42** and **2.43**).
- ◆ The patient is placed into intramaxillary fixation with rubber bands to guide the occlusion for 3 weeks.



Fig. 2.43 A larger segment of rib can be used in nonradiated patients. A nonabsorbable suture is placed through the cartilage of the rib graft and around the root of the zygoma to maintain the position of the graft in the condylar fossa during healing.



Fig. 2.44 One year postoperative result demonstrates excellent facial mandibular symmetry.

Patient Selection and Perioperative Management

The rib graft technique requires that there be no active infection or salivary contamination because these factors raise the risk of resorption or graft necrosis. Similarly, a radiated field, or a long segment reconstruction, increases the risk of graft failure. The rib graft reconstruction is ideal for short-segment defects in a nonirradiated patient. In the high-risk patient, a vascularized reconstruction should be considered.

Postoperatively, the patient remains in intramaxillary fixation for 3 weeks with rubber bands. A full liquid diet is prescribed for 3 weeks and during week 4 the patient is advanced to a soft diet until postoperative week 6. We prefer to order a panoramic x-ray or three-dimensional computed tomography (CT) scan postoperatively and at 6 weeks to assess the position and healing of the rib graft (**Fig. 2.44**).

◆ THE LONG SEGMENT CONDYLAR DEFECT

The long segment condylar-ascending ramus defect can be managed with a nonvascularized rib graft; however, the risk of graft failure is rather high (**Fig. 2.45**). In such cases, a vascularized graft, such as a fibular or scapular tip vascularized bone graft, offers an excellent option. Both donor sites provide a bone graft that can be contoured to fit within the glenoid fossa and accommodate the loading forces of mastication. The advantage of the fibular donor site is that it provides a vascularized skin paddle for those cases that require

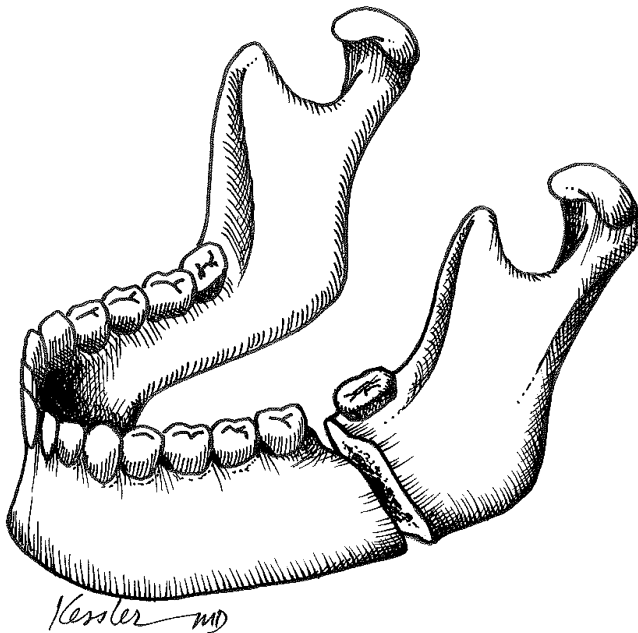


Fig. 2.45 Extensive defect of the ascending ramus.

intraoral or cutaneous coverage. The scapular tip can be harvested with the latissimus skin paddle; however, the muscle-skin paddle can be thick and bulky.

Option for Management: Fibular Free Flap

The fibular donor site provides an excellent source of vascularized bone with a skin paddle that can be used for more complex defects. Because the bone stock can be robust, careful attention should be dedicated to the position and continuity of the facial nerve, particularly in secondary mandibular reconstruction.

Surgical Technique and Considerations

- ◆ After harvesting the fibula graft, if necessary, an osteotomy can be performed to contour the bone graft, although this is commonly not necessary.
- ◆ The distal aspect of the bone graft that will be positioned in the glenoid fossa can be contoured by peeling back the distal periosteum and using a drill to soften and round the bony edges (**Fig. 2.46**). The periosteum can then be closed over the distal bone edge to provide a soft tissue interface between the fibular bone and the glenoid fossa.
- ◆ In those cases where the diameter of the fibular bone precludes safe placement into the glenoid fossa because the bone graft is too large in diameter, the bone graft can be divided vertically by bluntly peeling back the periosteum and performing a vertical osteotomy.
- ◆ Once the bone graft has been positioned, a single hole can be drilled through the distal bone graft and a

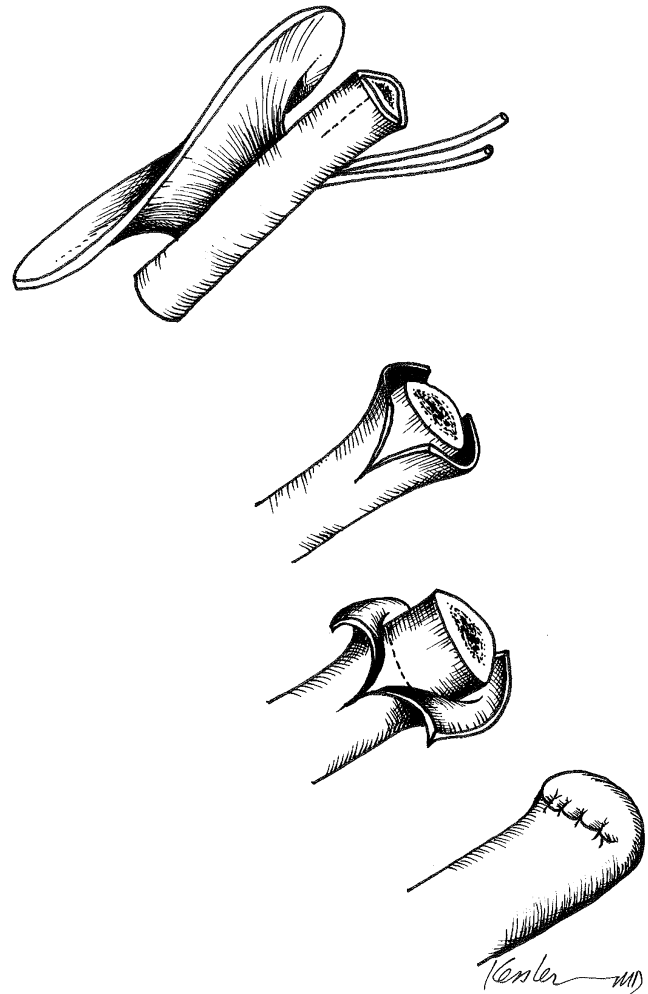


Fig. 2.46 The fibular bone graft can be used to reconstruct both the ascending ramus and the condylar joint by peeling periosteum back, resecting a segment of distal bone graft, and closing the periosteum over the bone graft to provide a neo-joint.

second hole can be drilled through the body of the zygoma. A 25-gauge wire of 2.0 Prolene suture can be passed through the holes in the bone graft and the zygoma to fixate the bone graft into the TMJ.

- ◆ The final stage of the reconstruction entails completing the adjacent soft tissue reconstruction with the skin paddle (**Fig. 2.47**).

Patient Selection and Perioperative Management

The fibular donor site is versatile and therefore can be used for a variety of complex defects involving the ascending ramus and TMJ. In those cases that involve a radical parotidectomy with facial nerve sacrifice, the lateral fascia can be associated with the skin paddle and oriented to provide a static facial suspension. The skin paddle can be used for either pharyngeal lining or skin resurfacing. A de-epithelialized portion of the skin paddle can also be folded to provide bulk and contour to the radical parotid defect.

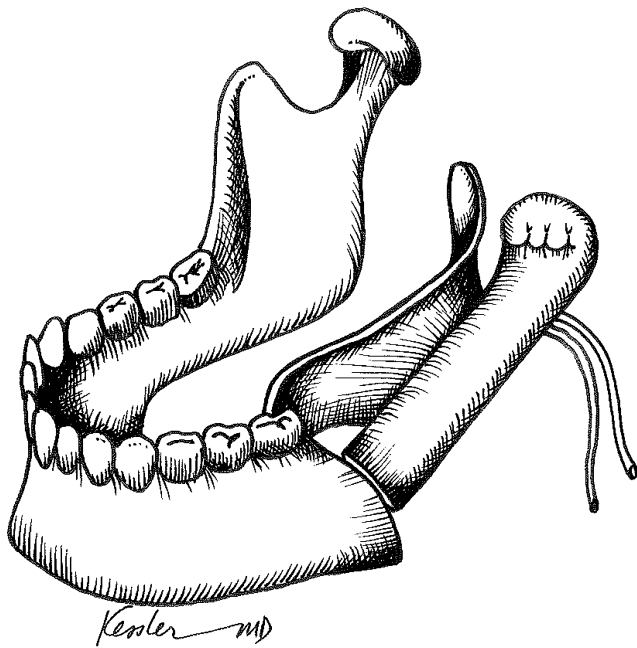


Fig. 2.47 The skin paddle can be oriented to reconstruct defects of the pharynx and floor of mouth.

Postoperatively, the patient remains in intramaxillary fixation for 3 weeks with rubber bands. A full liquid diet is prescribed for 3 weeks and during week 4 the patient is advanced to a soft diet until postoperative week 6. We prefer to order a panoramic x-ray or three-dimensional CT scan postoperatively, and at 6 weeks we assess the position and healing of the fibular graft.

◆ THE TOTAL MANDIBULAR DEFECT

Osteoradionecrosis and benign osseous disease of the mandible make up the two most common indications for complete mandibular replacement. Although there are several options for subtotal mandibular reconstruction, the fibular donor site is the only bone-containing flap that provides 25 cm of bone, enough to reconstruct the entire length of the mandible. The principles of total mandibular reconstruction are a blend of several concepts highlighted in the prior sections. The central concepts include careful presurgical consultation regarding the risks of surgery, discussion of the patient's expectations, and the plan for orodental rehabilitation.

Option for Management: Fibular Free Flap

The only option for reconstruction of the total mandibular defect is the fibula free flap. This is the only donor site that provides enough vascularized bone to span a condyle-to-condyle defect. Primary management tends to be less

complex than secondary reconstruction because removing the mandible primarily provides the surgeon with access to the glenoid fossa and a soft tissue envelope to accommodate the bone graft. In contrast, secondary reconstruction typically means that the surgical field is scarred, raising the risk of facial paralysis. Access to the TMJ requires careful identification and dissection of the facial nerve to prevent injury. In a scarred and radiated field, this necessary dissection can be a challenging endeavor. In addition, a soft tissue envelope must be established from condyle to condyle to accommodate the bone graft.

Surgical Technique and Considerations

- ◆ Prior to removing the mandible, the facial nerves should be identified so that the TMJ can be identified. Access to this area facilitates removal of the mandibular bone as well as placement of the fibular graft.
- ◆ Once the mandible has been removed, we place a 30-gauge wire around the lateral aspect of the zygoma or through a drill hole adjacent to this area in anticipation of securing the bone graft into the joint space.
- ◆ The bone can be fixated using a series of miniplates or a single reconstruction plate. We prefer the latter technique because preforming the plate is helpful in guiding the osteotomies and contouring of the bone graft.
- ◆ If the bone graft is plated ex vivo, the distal ends of the bone graft can be contoured using a 6- to 8-mm cutting burr so that they fit comfortably into the glenoid fossa.
- ◆ A single drill hole can be placed in each end of the distal bone graft to accommodate the transzygomatic wire.
- ◆ In the dentate patient, the intraoral defect can be closed primarily; however, in the radiated patient, a skin paddle may be necessary to facilitate healing. The challenge lies in the radiated patient that may require both intraoral lining and augmentation of the facial skin envelope to accommodate the bone graft. In these rare cases, a fasciocutaneous flap may be necessary.
- ◆ Prior to closure, it is imperative that the suprahyoid muscles be reattached to the symphysis of the neomandible. We also prefer that a hyoid advancement be performed by placing a 0.0 Prolene around the hyoid and around the mandibular plate in the symphyseal region. This technique facilitates laryngeal elevation, airway protection, and swallowing.
- ◆ Because the entire bone graft is used for total mandibular reconstruction, the vascular pedicle is limited in length. Either the anastomosis can be performed with the superficial temporal vessels or vein grafts can be used. The former is preferred because it optimizes the pedicle geometry and prevents kinking.
- ◆ Following the flap revascularization, both dentate and edentulous patients are placed into intramaxillary fixation with rubber bands to guide the occlusion.

Patient Selection and Perioperative Management

Choosing the appropriate patient for surgery usually applies to the patient considering secondary reconstruction because most patients undergoing primary mandibulectomy choose to undergo reconstruction. In either case, preoperative assessment of the lower extremity anatomy is required to identify congenital or acquired vascular anomalies that may preclude the use of the fibular donor site.

In those patients considering secondary mandibular reconstruction, a lengthy discussion related to the risks of surgery with an emphasis on facial paralysis is essential. It is also important that the patient have a clear understanding that speech and swallowing are an important part of the rehabilitation.

Postoperatively, patients are kept in intermaxillary fixation for a period of 6 weeks to allow for healing. Mandibular range-of-motion therapy is initiated after week 6. Nasogastric feedings are prescribed for 7 to 14 days depending on their prior radiation.

◆ CONCLUSION

Reconstruction of the oromandibular complex requires an appreciation of the anatomy that is essential to swallowing and speech. Although each of the donor sites offers unique advantages, no single donor site confers an overwhelming advantage for oromandibular reconstruction. The optimal functional outcomes are a result of a thoughtful approach to the reconstruction and an appreciation of the importance of tongue mobility, dental occlusion, and mandibular symmetry. It should be stressed that long-term functional success is often predicated on the adjunct procedures such as hyoid advancement, epiglottoplasty, and preservation of tongue mobility, and less a function of donor-site choice. Careful preoperative planning and multidisciplinary coordination will increase the likelihood of an optimal result.

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Palatomaxillary Complex Reconstruction

Eric M. Genden

The unique three-dimensional infrastructure of the maxillary skeleton serves both functional and aesthetic roles. The palate provides support for the upper dentition, whereas the maxillary complex helps to support the globe and the nasal airway. As an aesthetic scaffold, the maxilla is also responsible for the projection and form of the nose, cheek, and upper lip. The relationship between form and function make postablative reconstruction of this area a formidable task for the reconstructive surgeon. Prosthetic obturation, local soft tissue flaps, free bone grafts, pedicle and free soft tissue flaps, and vascularized bone-containing free flaps, have all been used for palatomaxillary restoration. Choosing the best reconstructive modality to achieve an optimal result requires a comprehensive evaluation of the soft tissue defect, the bone defect, and the quality and quantity of the remaining dentition.

Historically, tissue-borne prosthetic obturation was the only option for the orodental rehabilitation of postablative palatomaxillary defects. Although prosthetic obturation has several advantages, including immediate dental restoration without the necessity for further surgery, it is also associated with several shortcomings, most notably instability and poor retention. A breakdown in the oronasal prosthetic-tissue seal, characteristic of prosthetic instability, may lead to oronasal communication manifested by hypernasal speech and oral regurgitation. These shortcomings are accentuated in edentulous patients, irradiated patients, and those who have undergone extensive resections. Efforts to improve stability, and hence oral rehabilitation, have resulted in an improvement in prosthetic design.

Surgically created scar bands and the midline palatal bony shelf are critical factors that help to retain palatomaxillary prosthesis. Lightweight prosthetic material and dental clasps were later introduced as a method of improving retention. In 1978, Aramany¹ published a classification system of post-surgical maxillectomy defects and defined the biomechanics of the obturator framework for six categories of commonly occurring maxillary defects. He classified defects based on the remaining teeth and the surgical defect in an attempt to

guide the design of prosthetic dentures. By anticipating the functional leverage forces associated with mastication, he advocated a design that would equally distribute and neutralize these forces to best stabilize the prosthesis. Aramany's¹ work and subsequent publications² on this topic were instrumental in guiding the development and design of contemporary prosthetic obturator. However, achieving an optimal functional result, particularly in large palatomaxillary defects, is a significant challenge for prosthetics alone.

Palatal reconstruction using pedicled palatal, pharyngeal, and nasal septal flaps has a long history with less than ideal outcomes.³ However, the limited availability of local tissue restricted the application of these flaps to the restoration of only small defects. As the biologic behavior of palatal and sinus carcinoma became better understood, the oncologic necessity for en bloc resection led to more extensive postablative defects, often involving the orbit and zygoma. Over the past several decades, a more critical appraisal of the functional results of prosthetic restoration has led reconstructive surgeons to apply a host of newly described pedicled flaps, such as the deltopectoral flap,⁴ temporalis flap,⁵ and the forehead flap,⁶ to palatomaxillary reconstruction.

Primary surgical reconstruction of palatomaxillary defects has met with considerable opposition. Although palatal obturation permitted the close observation of the maxillectomy cavity, the most common site of recurrence, flap reconstruction prevents direct examination of the defect cavity. Until the last decade, primary reconstruction has been reserved for small, low-grade neoplasms of the palate. Furthermore, soft tissue reconstruction separates the oral and nasal cavities; however, obliteration of the maxillary cavity with bulky soft tissue may prevent the retention of a tissue-borne dental prosthesis. Until the introduction of bony palatal reconstruction, the use of soft tissue alone effectively partitioned the oral and nasal cavities but precluded the retention of a denture, leaving patients unable to tolerate anything more than a pureed diet.

The introduction of osseointegrated implants by Brånemark et al⁷ in the late 1970s offered a new mechanism for

the retention of prosthetic devices. Osseointegrated implants were first applied to the mandible serving as an anchor for implant-borne dental prostheses, thereby obviating the necessity for sufficient dentition for retention. The endosteal titanium fixtures are placed in the bone flap, where they are allowed to osseointegrate and not only anchor but also establish load sharing of the dental prosthesis, providing for more stable retention. The benefits of osseointegrated implants in masticatory function have been well described. Similarly, implant placement in the maxilla has been successful in achieving oral rehabilitation in palatomaxillary reconstruction.⁸ It is important to review briefly the three key elements to achieving successful retention and function of osseointegrated implants in the maxilla. Osseointegrated implants must be (1) anchored into sufficient bone stock, (2) vertically oriented, and (3) equally distributed across the load-bearing surface.

After an extensive palatomaxillary resection, the bone stock that remains available for implant placement is often insufficient. Optimally, 7 to 10 mm of bone is required for osseointegration and long-term retention. A portion of the nasal bones, the zygoma, and, in some cases, the inferior orbital rim may remain intact after a maxillary resection. Although these bones may be sufficient for the placement of non-load-bearing prosthetic devices (i.e., nasal or ocular prostheses), they are insufficient for long-term implant-borne dental retention.

Vertically oriented and equally dispersed placement of the implants is essential to long-term success. Implant placement into the zygoma results in oblique torque forces counteractive to the vertical loading forces of mastication. These counteractive biomechanical forces lead to loosening and eventual implant loss. In an effort to achieve successful implant stability through osseointegration, several techniques have been employed to restore bone to the maxilla. Free iliac bone, vascularized rib with latissimus dorsi and periosteal flaps,⁹ and vascularized cranial bone flaps¹⁰ were used in the 1980s. Although these methods provided bone to the region, it was often insufficient for implant placement and the soft tissue was commonly too bulky to permit the retention of tissue-borne dentures.

The application of microvascular reconstruction to the head and neck has greatly impacted the surgeon's approach to both defect restoration and functional rehabilitation. Superior functional results in mandibular reconstruction using vascularized bone-containing free flaps led to the application of the osteocutaneous scapular free flap,¹¹ followed by several publications describing fibular^{12,13} and iliac¹⁴ bone-containing free flaps for maxillary reconstruction. Vascularized bone-containing free flaps offer several benefits for primary maxillary reconstruction over traditional palatomaxillary obturation. This technique permits the single-stage transfer of vascularized soft tissue and bone; it facilitates restoring the separation of the oral and nasal cavities as well as providing bone adequate for the placement of osseointegrated implants. The mobility of the soft tissue paddles relative to the bone flap permits the restoration of complex three-dimensional defects of the palatomaxillary complex as well as relining the nasal and oral cavities. Probably the most significant advantage of free composite

Table 3.1 The Goals of Palatomaxillary Reconstruction

- Support the orbital contents
- Separation of the mouth and nose
- Reconstruct the palatal surface
- Reconstruct the lacrimal apparatus
- Provide facial symmetry
- Dental rehabilitation

flap reconstruction is the ability to rehabilitate the extensive palatomaxillary defect.

The biomechanical forces placed on a palatomaxillary obturator, particularly in extensive defects where the retentive surface is diminished, lead to a cascade of destabilizing forces. Reconstruction with autologous bone and soft tissue achieves the goals of palatomaxillary reconstruction (**Table 3.1**). It restores a permanent soft tissue seal, preserving oro-nasal competence, restoring nasal lining, and providing a fixed segment of bone ideal for dental rehabilitation.

◆ RELEVANT ANATOMY

The maxillary bones are paired structures formed by the right and left maxillae. The body of each maxilla is hollow and shaped like a pyramid with the base situated medially, adjacent to the nasal cavity. In considering the anatomy relevant to palatomaxillary reconstruction, the maxilla should be divided into *supportive buttresses* and *processes*. The former constitute the infrastructure of the maxilla essential for mastication, and the latter are responsible for the form of the palate and midface. Ideally, reconstruction of the palatomaxillary defect should address both anatomic units.

The anatomic complexity of the maxilla is related to its three-dimensional construct, which is a lattice-like structure supported by three separate paired buttresses. These buttresses, which have formed as an adaptation to the vertical forces of mastication,¹⁵ include the nasomaxillary buttress, the zygomaticomaxillary buttress, and the pterygomaxillary buttress.¹⁶

The nasomaxillary buttress extends from the anterior aspect of the alveolus adjacent to the piriform aperture and nasal process of the maxilla, to the superior orbital rim and frontocranial attachment. This buttress supports vertical stresses placed on the anterior maxilla. The zygomaticomaxillary buttress is situated laterally, extending from the lateral aspect of the alveolus to the zygomatic process of the frontal bone superiorly and the zygomatic arch laterally. The pterygomaxillary buttress is situated posteriorly, extending from the maxillary tuberosity to the cranial base by the pyramidal process of the palatine bone and the medial pterygoid plate.

The integrity of these buttresses is essential to providing a stable occlusal surface for the opposing dentition of the mandible. Furthermore, they allow for distribution of the masticator forces evenly across the skull base. Each buttress acts as a structural pillar providing both strength and maxillary position, which is roughly 45 degrees to the plane of the cranial base. Reconstruction of the palatomaxillary complex requires that at least two of the three buttresses be reestablished to evenly dissipate the vertical forces.

Classically, there are four processes related to the maxilla: the zygomatic process, the alveolar process, the palatine process, and the frontal process. The zygomatic and alveolar processes play a key role in the form of the lateral midface. The zygomatic process is responsible for the aesthetics of the malar eminence. Reconstruction of this process requires an appreciation of the horizontal and vertical planes of the zygoma. The horizontal position of this process is parallel but slightly below the Frankfort horizontal plane.¹⁷ The horizontal arch runs from the lacrimal fossa to the zygomatic process of the temporal bone. The vertical plane extends from the zygomatic process of the frontal bone to the lateral antral wall. The combination of these two planes defines the contour of the lateral cheek.

The alveolar process projects inferiorly from the infratemporal surface of the maxilla. Posteriorly, it projects beyond the third molar as the maxillary tuberosity. Both the vertical and horizontal positions of the alveolar process are important in providing the occlusal surface for the mandible. As mentioned earlier, the horizontal plane of the alveolar process is at a 45-degree angle to the skull base. The posterior projection of the maxillary tuberosity should be medial to the ascending mandibular ramus to prevent impingement on the coronoid process.

The palatine process is a medial projection of bone deriving from the nasal surface of the maxilla. Its significance in maxillary reconstruction is minimal. Similarly, the frontal process of the maxilla is a thick band of bone that lies in front of the ethmoids and articulates with the frontal bone superiorly. The frontal process plays an integral role in lending strength to the nasal and lacrimal structures; however, it is of little significance with regard to midface reconstruction.

Reconstruction of the maxilla requires reconstitution of the hard palate, lateral nasal wall, alveolus, the anterior face of the maxilla, and, in some cases, reconstruction of the body and the arch of the zygoma and orbital rim and floor. These structures are responsible for both the aesthetic characteristics of the midface as well as the functional properties such as a patent nasal airway and support of the globe. Reconstitution of the buttress system ensures a stable occlusal surface essential to functional mastication.

◆ BIOMECHANICAL CONSIDERATIONS

To achieve stabilization and retention of a prosthetic obturator, every effort should be made to enhance the favorable biomechanical forces and de-emphasize the counterproductive torque forces placed on the obturator. Planning the design of the obturator should begin with a preoperative consultation with a prosthodontist. Similarly, thoughtful intraoperative decisions help to maximize the remaining hard and soft tissues that will later complement retention of the obturator.

Surgical considerations for prosthetic rehabilitation should focus on the placement of a split-thickness skin graft within a palatomaxillary defect as well as the formation of tissue under cuts to aid in the creation of fibrous scar bands. Furthermore, the osteotomy cut adjacent to the defect should be made through an extraction site. Extraction of the

adjacent tooth should be performed prior to the anterior osteotomy. This preserves the alveolar housing around a tooth, which is critical to retaining the prosthesis.

The prosthetic prognosis, which refers to the functional success, is determined by (1) the size and location of the defect; (2) the quality, quantity, and location of the remaining dentition; and (3) the surface area of the remaining palate. A compromise in any of these factors impacts negatively upon the ability to effectively stabilize and retain a palatal obturator. The relationship between these factors results in a fulcrum line relative to the prosthetic framework. The position of the prosthetic fulcrum line is determined by the terminal abutment tooth closest to the maxillectomy defect. When three planes are drawn from the two terminal abutments to the opposite canine, a stable triangle is established (**Fig. 3.1**). The hypotenuse of the triangle represents the fulcrum line. When the defect enlarges, the area within the triangle diminishes as does the prosthetic stability. The

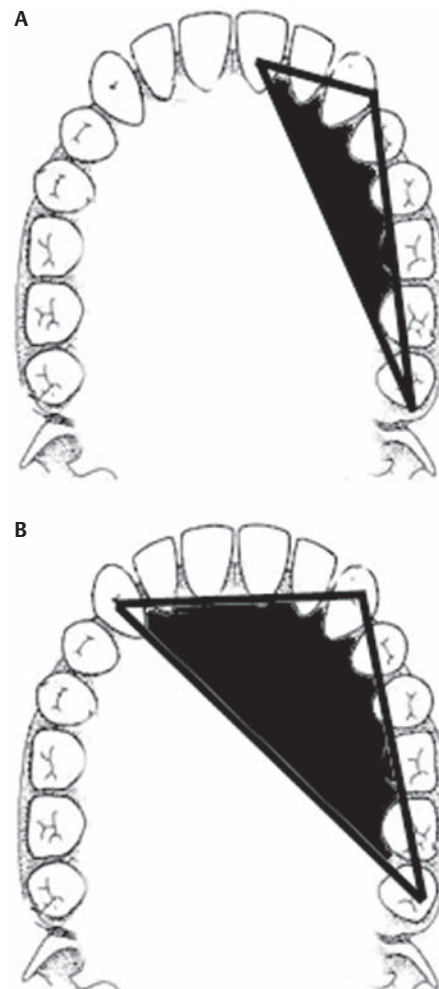


Fig. 3.1 Stability of a tissue-borne prosthesis. The position of the prosthetic fulcrum line (the hypotenuse shifts as the palatomaxillary defect increases in size). The area within the triangle is proportional to the cantilever forces; hence, the prosthetic instability. As the defect increases in size, the triangular area increases. Similarly, the instability of a prosthesis increases. Smaller defects (**A**) are more stable, whereas larger defects (**B**) are less stable.

rotation of the obturator framework along the fulcrum line occurs as a result of the differences in quality and quantity of supporting tissues on either side of the fulcrum line. The greater the rotational forces (referred to as *cantilever forces*), the greater the prosthetic instability. Aside from the intraoperative considerations mentioned above, there are several postoperative techniques that can be implemented in the design of the prosthesis that help to minimize the cantilever forces and thereby stabilize the prosthesis.

Clasp assemblies fixed to the remaining dentition are essential to neutralizing the adverse cantilever forces. For this reason, the root form and condition of the periodontium is paramount. In particular, the condition of the tooth closest to the defect plays an essential role in determining prosthetic prognosis. This tooth is exceedingly important because it will bear the greatest stress. Hence, an adequate root form of this terminal abutment is an important factor. This is exemplified by the large discrepancy between the superior root form of the canine tooth compared with that of the lateral incisor. Defects that require resection of the canine tooth and a portion of the premaxilla result in a terminal abutment tooth with an inferior root form, the lateral incisor. Furthermore, this defect results in a shortening of the palatal arch. As the arch shortens, the ability to clasp teeth perpendicular to the fulcrum line, thereby preventing rotational forces, is diminished.

The adverse forces placed upon a dental obturator include vertical dislodging force, occlusal vertical force, torque or rotational force, lateral force, and anterior-posterior force. Several publications have been devoted to techniques aimed at minimizing these forces.^{2,18,19} However, as the residual palate diminishes and the palatal defect enlarges, the cantilever forces become overwhelming, leading to prosthetic instability and a poor functional result.

Large defects adversely affect prosthetic retention in two ways. First, they leave less dentition available to clasp. Second, they are associated with a diminished retentive surface area. The combination of these two factors results in greater cantilever forces over the defect. As a result, large defects of the palate result in a tendency for the prosthesis to tip toward the defect. The fulcrum is positioned across two stable teeth, the canine and the third molar. Each has a characteristically strong root form. Furthermore, the dentition beyond the fulcrum line may be securely clasped. Techniques to neutralize these counterproductive forces become ineffective in extensive palatal defects. Stabilizing large palatal defects requires the supplementation of bone to increase the area of the palatal arch. This can be achieved by the addition of either vascularized or nonvascularized bone into which osseointegrated implants may be placed and a stable fulcrum line may be reestablished.

◆ CLASSIFICATION OF PALATOMAXILLARY DEFECTS

Since Ohngren's²⁰ original classification in 1933, there have been several classification schemes based on oncologic considerations that describe the anatomic boundaries of the

maxillectomy defect.^{21–23} There are few classification systems, however, that address an algorithm for reconstruction. Past reports aimed at addressing the reconstructive options for rehabilitation of the palatomaxillary defect focused on prosthetic design, with little discussion regarding surgical reconstructive options. Spiro et al²² proposed a classification system in 1997 that was relatively straightforward; however, it focused on “low,” or infrastructure, defects, and failed to specifically address the involvement of adjacent structures such as the orbit and zygoma. The vertical dimension of the maxillectomy defect was more appropriately dealt with by McGregor and McGregor,²³ yet this system incompletely addressed extensive palatal defects and the dilemma associated with prosthetic reconstruction of these defects.

Realizing that the technique employed for optimal maxillary reconstruction was largely dependent on the nature and extent of the defect, Davison et al²⁴ proposed a reconstructive algorithm based on a review of 108 cases using dental obturation, nonvascularized bone grafts, local flaps, regional flaps, and microvascular free tissue transfer. They divided patients into two broad categories of “complete” and “partial” maxillectomy defects. Although they proposed a wide range of reconstructive techniques, the failure to include a specific defect-oriented classification system outlining the remaining portion of the hard palate, dentition, orbit, and zygoma makes such a scheme difficult to apply as a reconstructive guide.

In 2000, Brown et al²⁵ reported a defect classification that is based on both the vertical and horizontal dimensions of a defect. The vertical component of the defect ranges from minor resections with no oroantral fistula, to radical maxillectomy defects with orbital exenteration. The horizontal component ranges from a small hard palate defect without involvement of dentition to a total palatotomy defect. According to Brown et al's scheme, the classification of the horizontal dimension of the defect is based on the remaining palatal surface. Although the residual palatal surface plays an important role in determining the best form of reconstruction for the edentulous patient, the dentate patient can rely not only on the remaining palate but also on the remaining dentition for retention. Furthermore, the status of the orbital floor and zygoma, which play an important role in both the function and cosmetic results of reconstructive surgery of the midface, are not specifically addressed. Defects involving either of these areas are poorly managed by prosthetic rehabilitation, and, as a result, these patients often benefit from hard tissue reconstruction. Brown et al's classification was the first to approach palatomaxillary defect classification with a multidisciplinary perspective, considering both surgical and prosthetic reconstruction to achieve a functional result.

In an effort to define a systematic approach to palatomaxillary reconstruction, the Mount Sinai group introduced a classification system and treatment algorithm based on the biomechanical factors inherent to the remaining palate (Figs. 3.2 and 3.3).²⁶ This approach divided palatomaxillary defects into three classes and two subclasses. The classification of each defect is dependent on the size and location of the defect in both the vertical and horizontal planes. In an effort to achieve the goals of optimal primary palatomaxillary

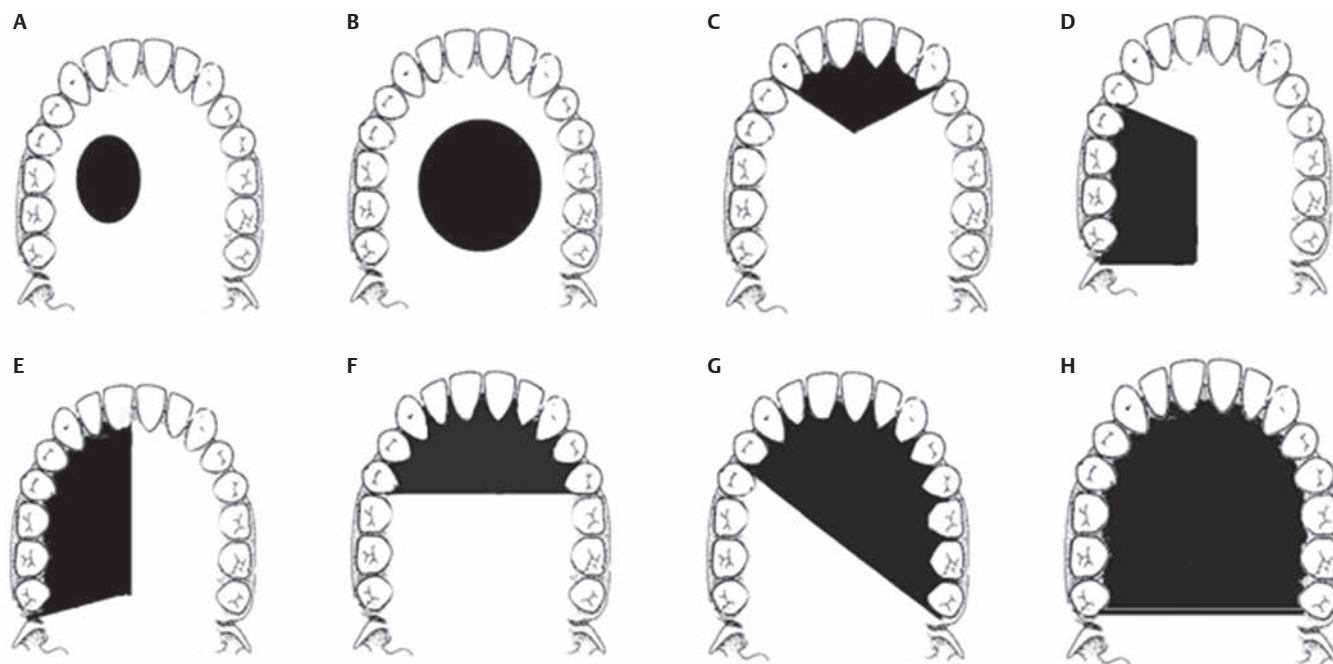


Fig. 3.2 The Mount Sinai palatomaxillary defect staging system. Class Ia defects (**A,B**); class Ib defects (**C,D**); class II defects (**E,F**); class III defects (**G,H**).

reconstruction, each defect is classified to support a reconstructive algorithm. Defects that involve the hard palate but not the tooth-bearing alveolus were categorized as class Ia (**Fig. 3.2A,B**). Defects that involved any portion of the maxillary alveolus and dentition posterior to the canines or that involved the premaxilla were categorized as class Ib (**Fig. 3.2C,D**). Defects that involved any portion of the tooth-bearing maxillary alveolus but included only one canine

were categorized as class II (**Fig. 3.2E,F**). And defects that involved any portion of the tooth-bearing maxillary alveolus and included both canines, total palatotomy defects, and anterior transverse palatotomy that involved more than half of the palatal surface were categorized as class III (**Fig. 3.2G,H**). Defects that involved the inferior orbital rim were categorized as subclass “f” (**Fig. 3.3A**), whereas defects that involved the body of the zygoma were categorized as

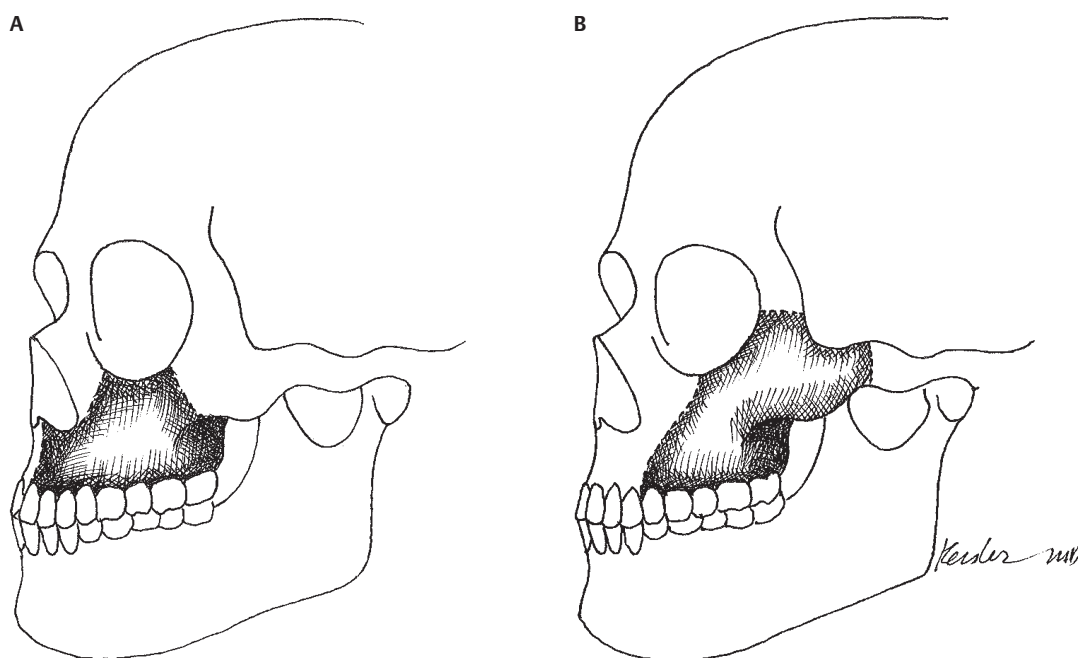


Fig. 3.3 The Mount Sinai palatomaxillary defect staging system. Subclass defects “f” (**A**) and subclass “z” (**B**).

subclass “z” (**Fig. 3.3B**). The reconstructive algorithm was designed so that class I defects could be considered for soft tissue reconstruction or prosthetic obturator; class II defects could be considered for prosthetic reconstruction or vascularized bone-containing free flap reconstruction; and class III defects could be considered for vascularized bone-containing free flap reconstruction.

◆ HARD PALATE DEFECTS

Isolated hard palate defects can range from a small oroantral fistula to a total hard palate defect. The approach to palatal reconstruction should be guided by the patient’s goals and the size of the defect. In general, the options include either prosthetic restoration or flap reconstruction. In many patients, prosthetic obturation offers a simple and immediate solution. In such cases, a preoperative mold can be fabricated so that a temporary prosthesis can be placed at the time of surgery. Obturators, however, have their drawbacks. Younger patients are often unhappy with the unnatural feel of an obturator. Many patients relate that obturators are socially awkward, and the need to wear a prosthesis during simple tasks such as drinking water or answering the phone is burdensome. Others find prosthetic hygiene onerous. This is particularly true for older patients, who complain of difficulty handling a prosthesis, and those with failing eyesight or debilitating arthritis. In spite of these drawbacks, prosthetic restoration provides patients with a nonsurgical single-stage option.

Depending on the nature of the defect, surgical reconstruction of the hard palate can be achieved with a minimal investment in time, and the quality of life and functional outcomes are often excellent. In cases where primary reconstruction is being considered, it is essential that the surgical margins be negative. In those cases where the margins are in question, it is advisable to fabricate an obturator and consider a secondary reconstruction once the final margin analysis has been completed.

Defects of the hard palate may result from a variety of etiologies including tumor extirpation, infection, and osteoradionecrosis. Isolated hard palate defects can be classified using a variety of classification systems; however, it is easiest to divide defects into those that are less than one-third the size of the palate and those that are greater than one-third the size of the hard palate. This is an effective distinction because it helps guide the options for reconstruction, as defects that are one-third the size of the hard palate or smaller lend themselves to adjacent tissue transfer techniques such as a palatal island flap or buccal flap. Larger defects often require free tissue transfer.

◆ THE PARTIAL HARD PALATE DEFECT

The objectives of hard palate reconstruction are to establish a partition between the oral cavity and the nasal cavity and preserve the contour of the native hard palate. When considering the options for reconstruction, it is important to use

a tissue graft that is hearty enough to maintain the partition between the oral and nasal cavities. Too often, mucosal grafts provide a satisfactory initial result, but over time they do not tolerate the mucosal stress. In contrast, tissue that is too bulky has an impact on a patient’s articulation and may preclude the retention of a denture if a denture is necessary. This is common in defects that are reconstructed with rectus or latissimus dorsi grafts. Ideally, the tissue graft should be thin and pliable but hearty enough to provide a reliable oro-nasal partition.

Option for Management: Restoration Using a Prosthetic Obturator

Defects that are less than one-third the size of the hard palate can be easily managed with a prosthetic obturator or a local flap. An obturator usually requires a preoperative assessment. This facilitates the fabrication of a temporary obturator that can be placed at the time of the ablative surgery. As discussed, this type of restoration is simple and nonsurgical; however, in patients who require postoperative radiation, an obturator can be painful and difficult to fit. Because the tissue is inflamed and swollen during external beam radiation, it is often challenging to achieve a reliable prosthesis–tissue seal. The isolated hard palate defect that involves the non–tooth-bearing portion of the hard palate is considered a stable defect because the tipping forces associated with an obturator are minimal. Clasps applied to the remaining dentition provide support for the prosthesis, and prosthetic retention is conferred by the remaining palatal surface.

In general, palatal prostheses designed for these defects are very stable. Patient dissatisfaction has led to the description of several locoregional and regional soft tissue flaps for the closure of the limited palatal defect. The mobility and accessibility of the oral tongue made this donor site a popular choice in the early 20th century. The obvious functional repercussions associated with the tongue flap have led to the use of several alternative donor sites including the temporalis flap, the buccal mucosal flap, and the palatal island flap. Most recently, free tissue transfer has been applied effectively to the rehabilitation of these defects.

Option for Management: Palatal Island Flap

There are a variety of buccal mucosal and palatal flaps that have been described for the management of this defect; however, the palatal island flap represents an optimal option for isolated palatal defects (**Fig. 3.4**). This flap is pliable enough to comfortably rotate into the defect, thin enough to assume the contour of the native palate, and, because the palatal island flap is a mucoperiosteal flap, it provides a hearty partition that heals reliably to the adjacent palatal tissue (**Fig. 3.5**). In nonirradiated patients with small to moderate-sized isolated palatal defects, the palatal island mucoperiosteal flap is our primary reconstructive option. First described by Millard^{27,28} and later popularized by

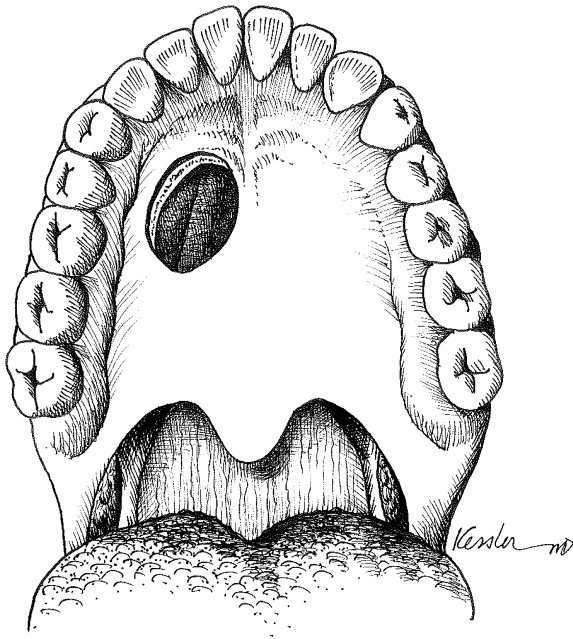


Fig. 3.4 Class Ia defect with a communication into the nasal cavity.

Gullane and Arena,²⁹ donor tissue based on a single greater palatine neurovascular pedicle, can be rotated and safely transposed across the hard palate (**Fig. 3.6**). The mucoperiosteum associated with the flap serves as a barrier to effectively separate the oral and nasal cavities. The secondary defect, which results from harvesting a palatal island flap, remucosalizes over a 3- to 4-week period; however, patients

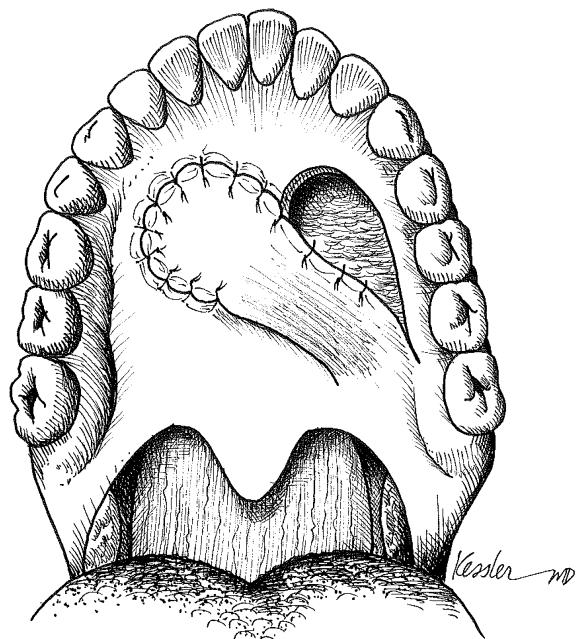


Fig. 3.6 The flap is sutured into the defect and the donor site is left to remucosalize, a process that takes 4 to 6 weeks.

can be started on an oral diet between 2 and 4 days postoperatively.

Palatal defects that do not cross the midline can easily be repaired using this single-stage local flap. Similarly, posterior palatal defects requiring resection of the maxillary tubercle and dentition posterior to the ipsilateral canine are also amenable to reconstruction using the palatal island flap. The mucosa remains sensate, which aids in mastication and oral transport, and, more importantly, coverage of this defect using the palatal island flap does not preclude the successful retention of a tissue-borne denture.

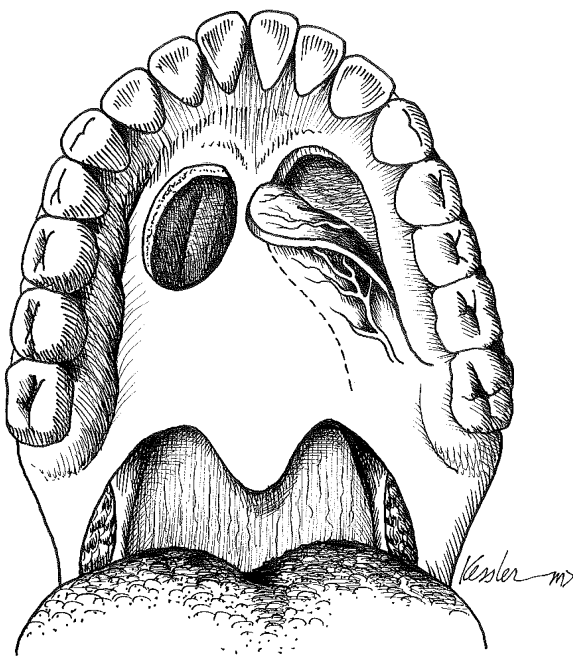


Fig. 3.5 The palatal island flap is raised in the subperiosteal plane from the contralateral palatine vessels and transferred to the defect.

Surgical Technique and Considerations

- ◆ The blood supply of the palatal island flap is the greater palatine artery and vein. The neurovascular pedicle emerges from the palatine foramen before entering into the soft tissue of the palatal mucosa.
- ◆ The posterior aspect of the palatine foramen is composed of a thin column of bone that can be fractured with a straight osteotome to release the neurovascular pedicle from the foramen and provide greater rotation of the flap if necessary.
- ◆ When designing the flap, it is important to carefully template the defect (**Fig. 3.7**). The flap dimensions should be designed to closely match the defect to prevent redundancy. As the flap rotates into position, it will shorten the flap length by between 10 and 30%, so it is important to account for this in the design of the flap.
- ◆ The flap is raised in the subperiosteal plane to prevent injury of the neurovascular bundle. The flap should be raised from anterior to posterior until the palatine

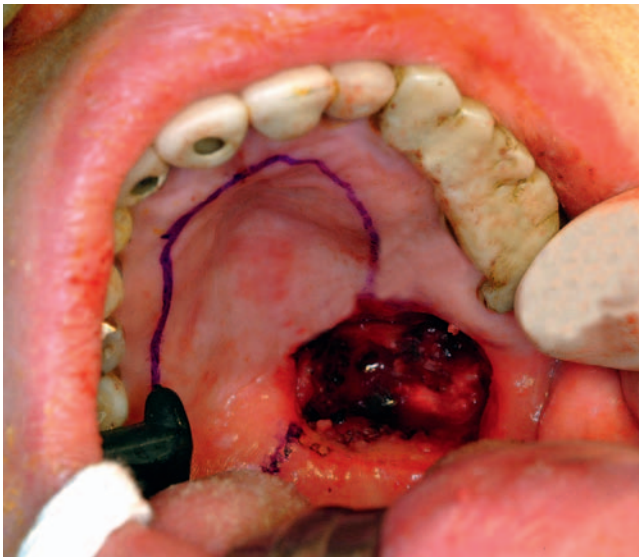


Fig. 3.7 Clinical case of a class I defect with a palatal island flap design.

foramen is identified. This provides the optimal length and rotation of the flap.

- ◆ When rotating the flap into position, special attention should be addressed to preventing a kinking of the palatine vascular pedicle (**Fig. 3.8**).
- ◆ Once rotated into the defect, the flap can be sutured into position with 2.0 Vicryl sutures. In some cases, small drill holes can be placed through the hard palate along the leading edge to secure the medial aspect of the flap.
- ◆ The healing over 3 to 6 weeks provides the opportunity for the donor site to remucosalize (**Fig. 3.9**).

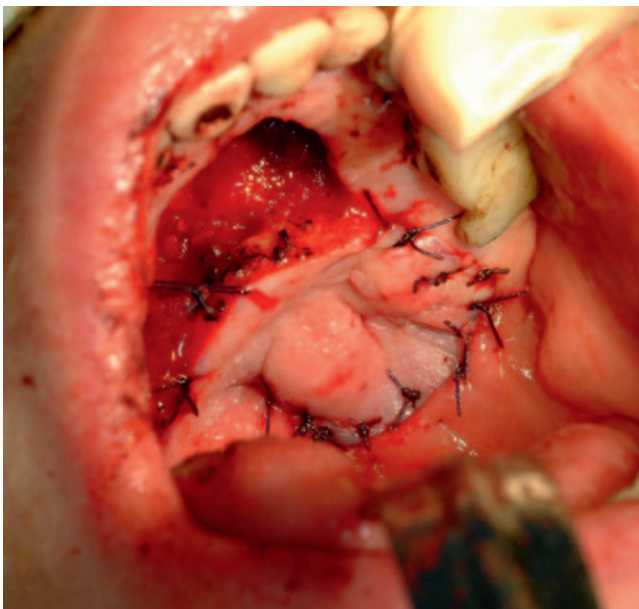


Fig. 3.8 The flap is sutured into place with absorbable sutures (2.0).



Fig. 3.9 Eight weeks after surgery the donor site has remucosalized and the contour of the hard palate is acceptable.

Patient Selection and Perioperative Management

The donor site requires little care. Typically the donor site is left to re-epithelialize without a dressing. Patients can be started on a clear liquid diet for 2 days, followed by a pureed diet for 2 days, and then advanced to a soft diet for 4 weeks. Oral hygiene should include peroxide and water (50:50) rinses three times a day and after meals. Pain control is seldom an issue. The donor site defect is not usually painful, and over the course of 4 to 6 weeks the donor site re-epithelializes.

There are few contraindications to using the palatal island flap for this approach; however, it should not be used in patients under the age of 5 years or in patients who have been previously radiated. Children under the age of 5 years may suffer a disturbance in palatal growth. Radiated patients may fail to re-epithelialize, and, in rare cases, osteoradi-
onecrosis may ensue.

Option for Management: Facial Artery Musculomucosal Flap

When defects are located laterally, the facial artery mucosal muscular (FAMM) flap may provide a suitable alternative for reconstruction.³⁰ The FAMM flap is an axial flap based on the facial artery as it courses deep to the buccal mucosa, lateral to the buccinator muscle, and medial to muscles of facial expression.

The flap is a mucosal muscular flap that is composed of the buccal mucosa and the buccinator muscle. This flap may be harvested based on either the inferior or superior vascular pedicle via retrograde flow through the angular vessels. This option is best applied to lateral defects wherein the flap can be designed with a wide base to include the axial blood supply and improve the viability of the flap. A Doppler

ultrasound can be used to improve the likelihood of capturing the nourishing vasculature.

◆ THE SUBTOTAL DEFECT OF THE HARD PALATE

Defects that are greater than one-third the size of the hard palate require free tissue transfer unless an obturator is used. This is because in most cases the remaining palate will not provide enough palatal tissue to achieve the appropriate coverage required for a palatal island flap. Similarly, buccal mucosal flaps are often inadequate. Prosthetic restoration or free tissue transfer are usually the most appropriate options, although several other local regional flaps have been described. Because the alveolus remains intact, bony reconstruction is unnecessary.

Option for Management: Radial Forearm Free Flap

The radial forearm free flap is an excellent option for extensive hard palate defects and for hard palate defects that involve a limited portion of the alveolus. It is indicated when the defect is too extensive to allow for a palatal island flap reconstruction or when a palatal island flap is contraindicated (**Fig. 3.10**). The radial forearm is thin and pliable, so it will conform to the natural contour of the native palate, yet hardy enough to provide a reliable oronasal partition. Typically, patients are happy with the permanency of the reconstruction. Functionally, patients are able to eat and speak normally, and for patients who require a tissue-borne

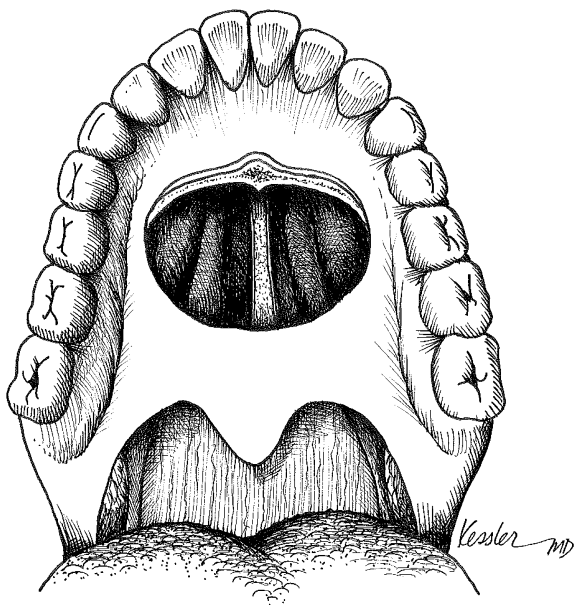


Fig. 3.10 Class Ia defect in the central palate. The defect communicated with the nasal cavity.

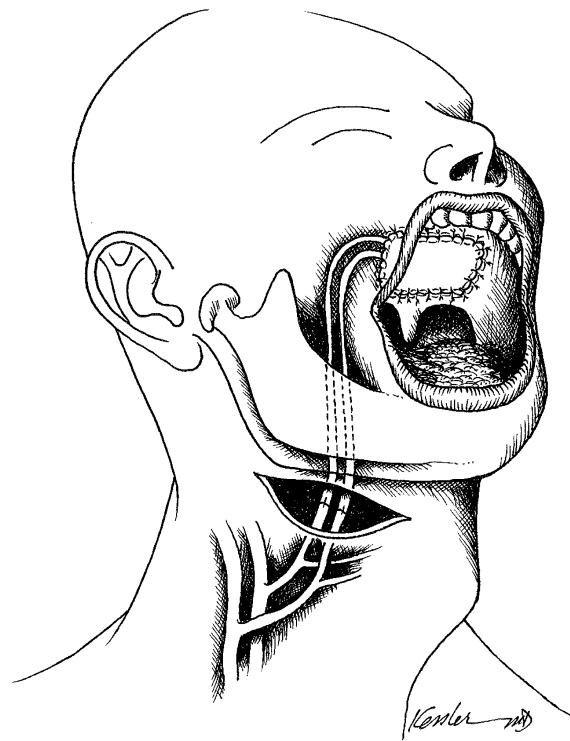


Fig. 3.11 The radial forearm free flap is used to reconstruct this defect. The vascular pedicle is drawn down into the neck through a submucosal tunnel medial to the mandible.

denture, the radial forearm does not hinder denture retention or stability.

For patients who seek an alternative to prosthetic rehabilitation, the fasciocutaneous radial forearm free flap offers an ideal source of donor tissue for the reconstruction of large palatal defects. The radial forearm free flap is designed so that the cutaneous paddle serves to reline the oral palatal surface and a fascial component is raised adjacent to the cutaneous paddle so that it can be folded to provide nasal lining. The pedicle can be passed through a subcutaneous tunnel superficial to the mandible or deep to the mandible to gain access to the facial vessels for the vascular anastomosis (**Fig. 3.11**). In our experience, we find this method of reconstruction reliable and effective in achieving a permanent separation of the oral and nasal cavities and has become our primary choice for reconstructing these select defects of the palate in patients who have no medical contraindications (**Fig. 3.12**).

Although large palatal defects can be successfully managed with a prosthetic obturator, the inconvenience associated with maintaining oronasal hygiene and the necessity of relying on a prosthesis for communication and eating can compromise a patient's quality of life. Soft tissue reconstruction of these defects with a local palatal flap, a submental island flap, or a fasciocutaneous radial forearm free flap offers patients a single-stage reconstruction that obviates the need for a palatal obturator without interfering with the use of a tissue-borne denture.

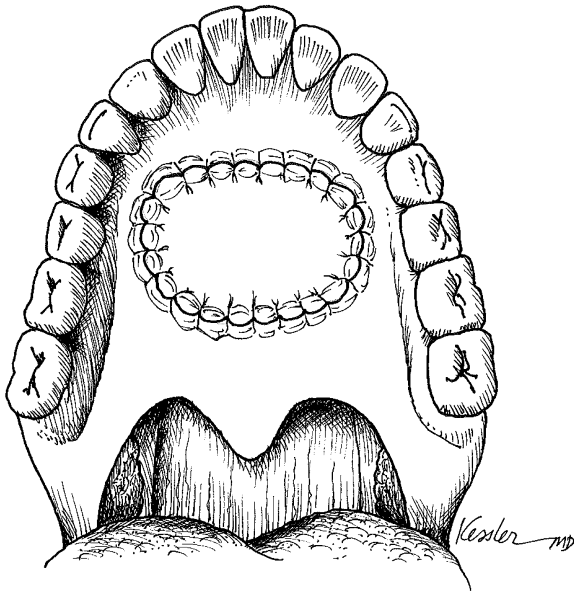


Fig. 3.12 The skin paddle partitions the oral cavity from the nasal cavity.

Surgical Technique and Considerations

- ◆ Once the margins have been assessed and the defect has been finalized, the donor vessels for the microvascular anastomosis should be isolated and a subcutaneous tunnel from the palatal defect to the donor vessels should be created (**Fig. 3.13**). The donor vessels, which are commonly the transverse cervical artery and vein or the facial artery and vein, should be dissected and isolated.
- ◆ Although passing the vascular pedicle medial to the mandible is preferable, on occasion a pathway lateral to the mandible may be used. In such cases, the marginal mandibular nerve should be identified and protected. Passing the vascular pedicle deep to the nerve minimizes the likelihood of nerve injury.



Fig. 3.13 Clinical case of a central hard palate defect with communication into the nasal cavity.

- ◆ If the vascular pedicle is too long, the facial vessels may not provide the ideal geometry. Redundancy of the vascular pedicle can lead to kinking and thrombosis, and therefore the superior thyroid artery and external jugular vein or the transverse cervical system may provide a better option. These sites allow the vascular pedicle to travel a straight path and decrease the potential for kinking and thrombosis.
- ◆ After the donor vessels have been isolated and the subcutaneous tunnel has been created, the radial forearm free flap skin paddle can be designed. Ideally, it should be designed using a template so that the skin paddle closely matches the defect (**Fig. 3.14**).



Fig. 3.14 Flap design. The flap is designed (**A**) so that the skin paddle is the approximate size of the palatal defect, and a distal fascial component of the flap can be used to reline the nasal cavity (**B**).



Fig. 3.15 Five days postoperatively, the flap is healing and the patient can begin an oral liquid diet.

Redundancy of the skin paddle will only hinder the final result. The skin will be used to reline the palate while the fascia opposite the skin will serve as lining for the floor of the nose.

- ◆ Before suturing the skin paddle into the palatal defect, the vascular pedicle of the flap should be thinned and excess fat should be trimmed to facilitate passing the vascular pedicle through the subcutaneous tunnel. The pedicle should then be passed through the subcutaneous tunnel and positioned adjacent to the donor vessels.
- ◆ The forearm skin paddle can be sutured into the palatal defect using 2.0 Vicryl suture. Once this is complete, the vascular anastomosis can be completed (**Fig. 3.15**).
- ◆ A passive drain is left in the neck at the site of the microvascular anastomosis.
- ◆ Long-term healing provides a natural contour to the palatal arch (**Fig. 3.16**).

Patient Selection and Perioperative Management

Postoperatively, parenteral nutrition is administered through a nasogastric feeding tube for 5 days, after which the patient is started on a liquid diet for 2 days, a puree diet for 2 days, and advanced to a soft diet for 2 days before beginning a regular diet. A nasal trumpet can be placed immediately postoperatively if there is concern of excessive stress on the palatal reconstruction. We restrict the patient from nose blowing and encourage mouth-open sneezing to prevent excessive stress on the suture line during the first two post-operative weeks.

In the early postoperative period the patient may experience a serosanguineous nasal discharge and nasal obstruction. However, over the course of 8 weeks the floor of the nose will epithelialize and the intranasal swelling will regress. As a result, the patient will develop an improved nasal airway. During the healing process, we advocate saline



Fig. 3.16 Two months postoperatively, the flap has integrated into the oral cavity and the nasal lining has remucosalized.

nasal douches eight to 10 times per day for hygiene and to encourage healing.

◆ MAXILLECTOMY DEFECTS

Partial maxillectomy defects can be divided into hemimaxillectomy defects and subtotal maxillectomy defects. The hemipalatectomy defect is the most common palatomaxillary defect and represents a controversial reconstructive dilemma.

Traditionally, prosthetic obturation has been considered the gold standard of therapy for such defects. Characteristic of the hemipalatectomy defect, the anterior abutment tooth is either the medial or lateral incisor. Retention is provided by framework designs that clasp the incisor and, in an effort to distribute the load, commonly splint two or more adjacent teeth. However, in spite of load-sharing prosthetic designs, the inadequate root form of the incisors make stabilization of the prosthesis difficult. The hemipalatectomy defect shifts the fulcrum line to an unfavorable position, leading to increased tipping forces. As a result, obturated patients often have difficulty with mastication. The unfavorable forces are a particular problem in the edentulous patient or in previously irradiated patients whose teeth are either absent or poorly suited to withstand the stresses of a clasp.

Similar to prosthetic restoration, soft tissue reconstruction using pedicled flaps^{5,10} or free tissue transfer^{31,32} has been described but commonly results in adverse functional consequences. Although soft tissue flaps are effective for relining the oral palate and separating the oral and nasal cavities, a soft tissue flap obliterates the retentive properties of the maxillectomy defect, which may prevent the retention of a tissue-borne palatal prosthesis for dental restoration. Furthermore, the absence of bone prevents the

placement of osseointegrated implants. As a result, patients are left without the opportunity for functional dental rehabilitation.

In contrast, several recent reports, including our own experience, demonstrate that single-stage reconstruction of these defects can be effectively accomplished with a bone-containing free flap. Although some authors have advocated the prosthetic reconstruction of all hemipalatectomy defects, others feel that defects involving any more than two thirds of the hard palate are functionally unstable.^{33,34} The reconstruction of these defects with vascularized bone serves to stabilize these forces by providing a rigid infrastructure as well as providing bone capable of retaining osseointegrated implants.

Several attempts to combine a fasciocutaneous flap^{22,35} or a temporalis flap³⁶ with free bone grafts have been made to address this problem. Choung et al³⁵ advocated using a parietal osteofascial flap with vascularized cranial bone grafts for maxillary reconstruction. Although cranial bone grafts can be stacked and wrapped in vascularized tissue to help preserve the bone stock and therefore accommodate osseointegrated implants, success with this technique is limited because of poor bone graft vascularization and the resultant bone resorption. In addition, the reconstruction of extensive defects is limited by the amount of available donor bone. Although free nonvascularized bone grafts are an attractive alternative, our experience has been that this is an inadequate method to achieve long-term retention of osseointegrated implants, particularly in extensive defects or in previously irradiated patients.

The goal of reconstructing the hemimaxillectomy defect is twofold: first, to shift the fulcrum line away from the midline, thereby decreasing the tipping forces and improving the distribution of masticatory forces; and second, to address the vertical component of the defect. Reconstruction of the hemipalatectomy defect using vascularized bone-containing free flaps offers several unique advantages for orodental rehabilitation that cannot be realized with other forms of prosthetic or soft tissue reconstruction. Most importantly, free tissue transfer of a composite flap allows for the bony restoration of the absent maxillary alveolus. The placement of osseointegrated implants and subsequent fitting of an implant-borne denture provides these patients with an optimal form of restoration without the inconvenience or instability associated with prosthetic appliances.

◆ THE INFRASTRUCTURE MAXILLECTOMY DEFECT

The infrastructure maxillectomy defect is isolated to the lower alveolar and horizontal palatal shelf (Fig. 3.17). Because the infrastructure defect has no vertical component, the fibular graft, the scapular graft, or the iliac crest graft can be oriented horizontally to reconstruct the infrastructure defect. Choosing the appropriate donor site depends largely on the amount of bone that is required and the body habitus of the patient. Each donor site has advantages and disadvantages. Although the iliac and fibular donor sites provide

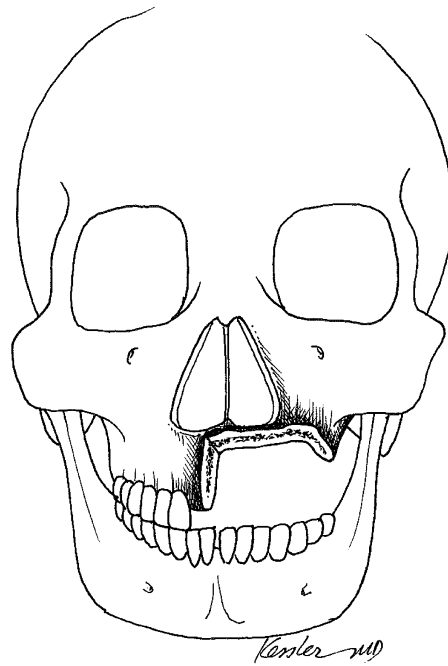


Fig. 3.17 The partial infrastructure maxillectomy defect.

excellent bone stock for implant retention, the scapular tip provides only a thin plate of bone that may require bone grafts if osseointegrated implants are planned (Fig. 3.18). In contrast, a thin plate of bone may be ideal in the select

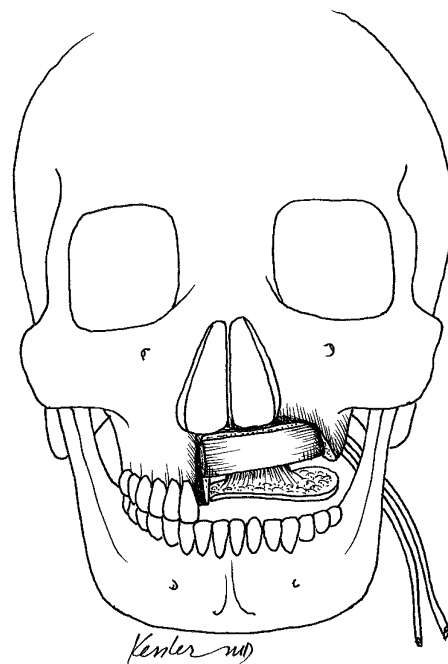


Fig. 3.18 The partial infrastructure maxillectomy defect can be managed with a variety of vascularized bone-containing free flaps including the fibular free flap. The skin paddle can be oriented to reline the oral palatal defect, and the vascular pedicle is drawn into the neck, medial to the mandible, to approximate with the facial vessels.

patient. Other considerations include the body habitus of the patient. Patients with a high body mass index may provide a thick skin paddle that is suboptimal for maxillary reconstruction. Choosing the most appropriate donor site requires a careful assessment of the defect and the donor tissue.

Option for Management: Fibular Free Flap

When the fibular donor site is used, the bone can be fashioned into an alveolar arch and fixed to the remaining native maxilla. The skin paddle can be used to resurface the palate and nasal floor.

Surgical Technique and Considerations

- ◆ The fibular donor site is particularly well suited for this defect when 1 to 2 cm of vertical height is required. The osteocutaneous architecture of the fibular donor site can be easily tailored to the bony defect, and the skin paddle can be used to reline the palate (**Fig. 3.19**).
- ◆ Once the defect is established, a subcutaneous tunnel lateral or medial to the mandible should be completed to pass the vascular tunnel to the donor vessels in the neck.
- ◆ If palatal lining is required to restore the defect, the contralateral fibular donor site should be harvested to



Fig. 3.19 Clinical case. The fibula is fixed to the adjacent maxilla with two-point fixation with mini-reconstruction plates. The skin paddle is oriented to reline the oral cavity.



Fig. 3.20 Several weeks postoperatively, the flap has contoured to the native palate.

- provide a skin paddle that can be used to reline the palate.
- ◆ Because the defect typically requires a small bone graft, the vascular pedicle can be dissected from the fibular bone to lengthen the vascular pedicle.
- ◆ The bone can be fixed to the free margin of the native maxilla with titanium miniplates.
- ◆ The skin paddle should be rotated into the oral cavity to reline the oral palatal defect (**Fig. 3.20**). Vicryl suture is used to suture the fibular skin paddle to the free edge of the native palatal mucosa.
- ◆ The microvascular anastomosis should be completed following the fixation of the bone graft.
- ◆ If the bone is appropriately fixed, the graft will support osseointegrated implants (**Fig. 3.21**).
- ◆ Orodental restoration provides excellent functional and cosmetic restoration (**Fig. 3.22**).



Fig. 3.21 Osseointegrated implants can be placed for dental rehabilitation primarily or secondarily.



Fig. 3.22 Final oral-dental restoration provides an excellent cosmetic and functional result.

Patient Selection and Perioperative Management

Like any bone graft reconstruction, a minimum of 6 weeks is required for the graft to heal (**Fig. 3.23**). Patients are maintained on a soft diet to reduce the stress on the healing graft. Radiated patients are restricted to a soft diet for 10 weeks because bone healing may be delayed.



Fig. 3.23 Three-dimensional computed tomography (CT) scan demonstrates the position of the fibular bone graft and the two-point fixation.

Most patients with an infrastructure defect are good candidates for a fibular reconstruction unless the defect is less than a centimeter in vertical height. Although the fibula can be decorticated, a less substantial graft such as the scapular tip may be more appropriate.

Option for Management: Reconstruction Using the Scapular Donor Site

The scapular donor site offers the unique advantage of two separate bone grafts based on two separate blood supplies. The ability to harvest the lateral scapular border based on the circumflex scapular artery and the scapular tip based on the angular artery allows for the reconstruction of complex defects of the palate and combined palatomandibular defects. Similarly, the ability to rotate the skin paddle relative to the bone graft aids in the reconstruction of complex postablative defects that may require both intraoral lining and external skin resurfacing. Recognizing the advantages of this donor site, early cases of bony reconstruction of the palate were performed using the scapular donor site.³⁷

Because the scapular tip is nourished by the angular artery, a branch of the thoracodorsal, the scapular tip provides an excellent option for infrastructure defects with a minimal vertical defect.

Surgical Technique and Considerations

- ◆ The flap harvest requires that the thoracodorsal artery and vein are dissected down to the takeoff of the angular branch. Once the angular branch is identified, the scapular tip can be safely harvested using a reciprocating saw.
- ◆ The scapular tip is harvested with overlying vascularized muscle that can be used as a bed for a skin graft or may be left to mucosalize secondarily.
- ◆ The angular vessels and the thoracodorsal extension provide excellent pedicle length so that vein grafts are not typically necessary.

Patient Selection and Perioperative Management

The scapular tip can be harvested with the overlying muscle that can either be left to epithelialize or skin grafted. Nasogastric tube feeds are administered for 7 days to aid in the healing process. The muscle will epithelialize over the course of 4 weeks in nonradiated patients, but may take 6 to 8 weeks in radiated patients. Skin grafting offers a more immediate alternative. Daily peroxide rinses are administered to provide hygiene and foster healing.

The scapular tip reconstruction is an excellent option for defects with minimal vertical bone loss. The bone stock may not be sufficient to accommodate osseointegrated implants, particularly in women and younger patients. In such cases, bone grafts may be necessary to augment the bone stock.

◆ THE ANTERIOR PALATAL DEFECT

Reconstruction of the premaxillary defect can be accomplished quite successfully with a prosthetic obturator; however, as the defect increases and the remaining hard palate and posterior dentition diminish, orodental rehabilitation becomes a more difficult challenge. Anterior transverse palatal defects involving more than one half of the hard palate lead to overwhelming tipping forces placed on the anterior alveolar arch. The loss of the nasomaxillary buttress and its associated anterior alveolar arch prevent an equal distribution of forces on the remaining palate. This is exemplified by biting into an apple, whereupon the axial forces on the incisors produce a rotational effect on the prosthesis.

In an effort to achieve retention during mastication, framework designs have been fabricated to clasp the remaining teeth. Excessive levering forces, however, commonly lead to destabilization of the prosthesis. Furthermore, the stress placed on the clasped abutment teeth commonly leads to dental wear with eventual loss of the abutment teeth. Placement of osseointegrated implants in the remaining bone of the posterior alveolus may be successfully performed for the restoration of smaller defects; however, larger defects cannot be appropriately rehabilitated with this technique. The bone of the posterior maxillary alveolus is inadequate for the retention of osseointegrated implants, and the torque forces are too great anteriorly to withstand long-term retention.^{38,39} As alluded to earlier, the ideal biomechanical relationships can be achieved if the osseointegrated implants are placed parallel to the loading forces.⁴⁰ However, the absence of the nasomaxillary buttress leaves only the zygomatic bone in the superior aspect of the defect cavity, which is inadequate for long-term retention. Reconstruction of the anterior transverse palatectomy can be achieved with bone-containing free flaps from several donor sites, including the scapula, fibula, iliac, and the osseocutaneous radial forearm free flap.

Option for Management: Osseocutaneous Radial Forearm Free Flap

The osseocutaneous radial forearm free flap provides a limited amount cortical bone with a pliable skin paddle. Although the bone graft is not ideal for mandibular reconstruction, it is well suited for small alveolar palatal defects. Although rare, occasionally an isolated anterior palatal defect may confront the reconstructive surgeon. Bony reconstruction of the anterior palatal arch with an osseocutaneous radial forearm free flap is often sufficient to provide the infrastructure necessary to support a tissue-borne or implant borne denture.

Surgical Technique and Considerations

- ◆ As previously described, up to 30% of the radial bone can be harvested in a boat-shaped design with a vascularized skin paddle.

- ◆ The bone can be shaped with a series of osteotomies that can be fixed with mini-plates or 25-gauge wire.

Patient Selection and Perioperative Management

Defects of the anterior maxilla that are greater than half the palatal area often require a substantial volume of bone that can be harvested from the scapular tip; however, defects less than half the palatal surface area require less bone. The radial forearm osseocutaneous donor site is ideal for this defect. Although the radial bone is not well suited for osseointegrated implants, bone grafts can be used to augment the radial bone for the retention of implants.

The most important aspect of the perioperative care is maintaining bone graft stability during the healing process. We keep patients on a liquid diet for 4 weeks to promote bone graft healing.

Option for Management: Reconstruction Using the Scapular Tip

For anterior palatal defects that are greater than 50% of the hard palate, the scapular tip offers an excellent option for reconstruction (Figs. 3.24 and 3.25). When the tip of the scapula is oriented horizontally, the bone graft is ideal for shallow anterior defects (Fig. 3.26).

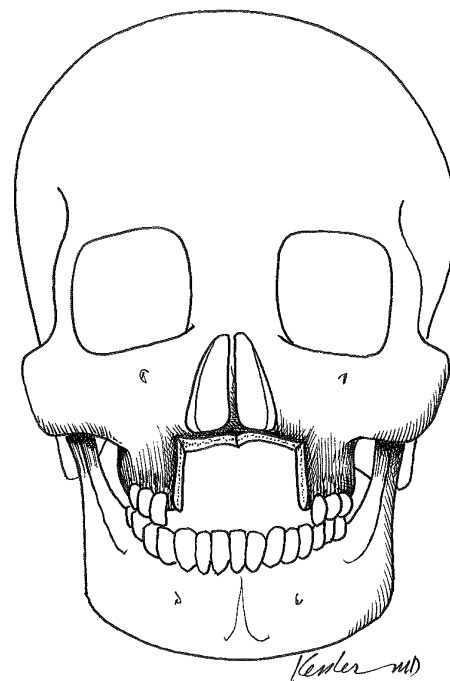


Fig. 3.24 The anterior palatal defect.

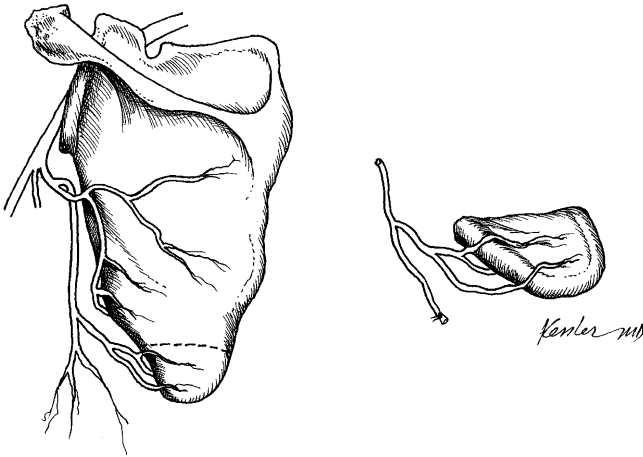


Fig. 3.25 The scapular tip provides an excellent source of bone for anterior palatal defect reconstruction. Based on the angular branch of the thoracodorsal, the vascular pedicle is 8 to 12 cm long, making it an ideal donor site for maxillary reconstruction.

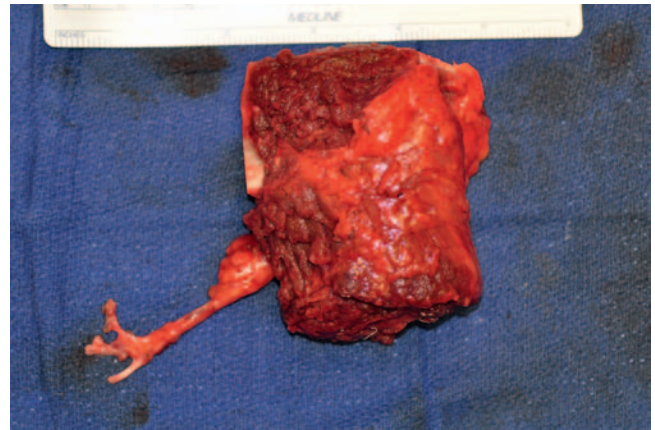


Fig. 3.27 Clinical case. The scapular tip with the angular branch of the thoracodorsal artery. The teres muscle is harvested with the bone graft to line the oral cavity.

Surgical Technique and Considerations

- ◆ The scapular tip is harvested with the angular artery pedicle. The teres muscle is harvested with the bone graft and will be used to provide oral palatal lining (**Fig. 3.27**).
- ◆ The bone graft is fixed posterior to the cut edge of the remaining native palate with titanium 1.5-cm

mini-plates. The bone can also be fixed anterior to the remaining nasal crest if necessary (**Fig. 3.28**).

- ◆ The vascular pedicle is passed through the buccal space medial to the mandible and aligned with the facial vessels.
- ◆ The teres muscle is used as lining and sutured to the cut edge of the posterior palatal mucosa. The muscle will remucosalize over several weeks (**Fig. 3.29**).

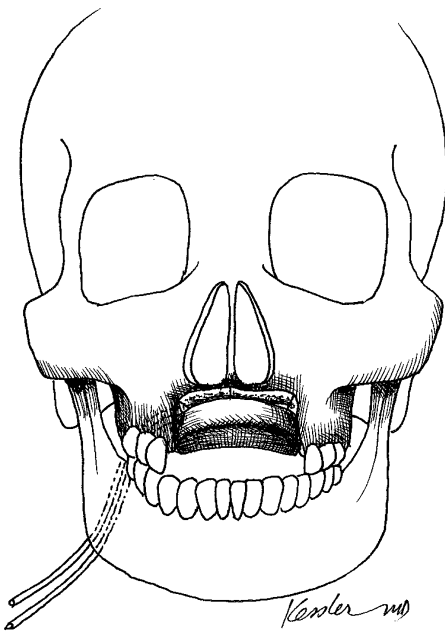


Fig. 3.26 The scapular bone graft can be placed horizontally and the teres muscle is used to relined the oral palatal defect.

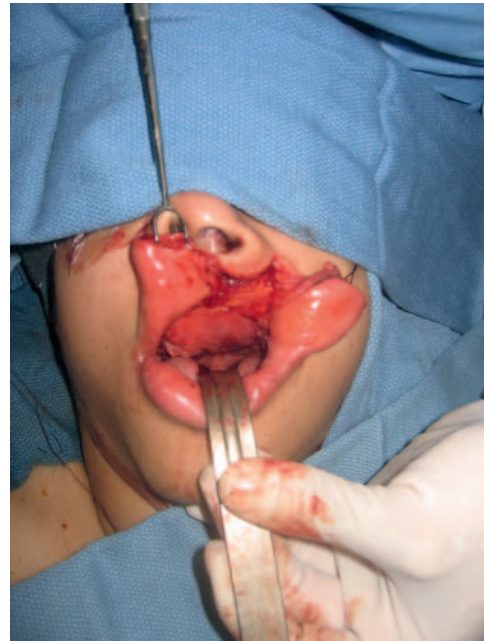


Fig. 3.28 The bone graft is fixated with miniplates to the posterior maxilla. The teres muscle is folded over the bone graft and sutured to the posterior free edge of the palatal mucosa.



Fig. 3.29 Three weeks postoperatively, the muscle has started to atrophy and the teres muscle begins to remucosalize.

Patient Selection and Perioperative Management

The scapular tip provides a thin bone graft that remains cartilaginous until the second decade of life. Although the bone graft fits well into anterior palatal defects, the bone is not typically substantial enough for osseointegrated implants unless free bone grafts are placed secondarily (**Fig. 3.30**). Postoperatively, the muscle will remucosalize over the course of 4 to 6 weeks. The contour and cosmetic results are predictable and usually satisfactory (**Fig. 3.31**). We recommend that patients remain nil per os (NPO) for 10 days after surgery and then remain on a liquid diet for 4 weeks to allow the bone graft an opportunity to heal.



Fig. 3.30 Three-dimensional CT scan demonstrates the horizontal position of the scapular bone graft and the posterior fixation.



Fig. 3.31 One-year postoperative evaluation demonstrates excellent cosmetic restoration of the maxilla.

◆ HEMIMAXILLECTOMY DEFECT WITH ORBITAL FLOOR PRESERVATION

Option for Management: Fibular Free Flap

When the orbital floor is preserved and the orbit and the canthus are supported, a variety of donor sites can be used to reconstruct the hemimaxillectomy defect (**Fig. 3.32**). The focus of the reconstruction should be directed toward reestablishing the bony alveolus (**Fig. 3.33**). Any of the vascularized bone-containing free flaps can be used to reconstruct this defect; the vertical component of the defect is less crucial. The fibular donor site provides an excellent source of bone with ideal vascular pedicle length but fails to provide the bone necessary to address the maxillary face. This can be managed with either a vertically oriented scapular or iliac crest graft or a fibular bone graft with a soft tissue or mesh augmentation.

Surgical Technique and Considerations

- ◆ The optimal donor site for reconstruction of the hemimaxillectomy defect depends on the extent of the vertical defect. In those defects where the orbital floor and zygoma are preserved, the fibular, iliac, or scapular donor sites can be used. Because the fibular donor site provides the advantages of a two-team harvest and the potential for a long vascular pedicle, it is an excellent choice.
- ◆ The fibula should be harvested from the donor leg that is contralateral to the maxillectomy defect to allow the skin paddle to be used to line the neopalate (**Figs. 3.34 and 3.35**).

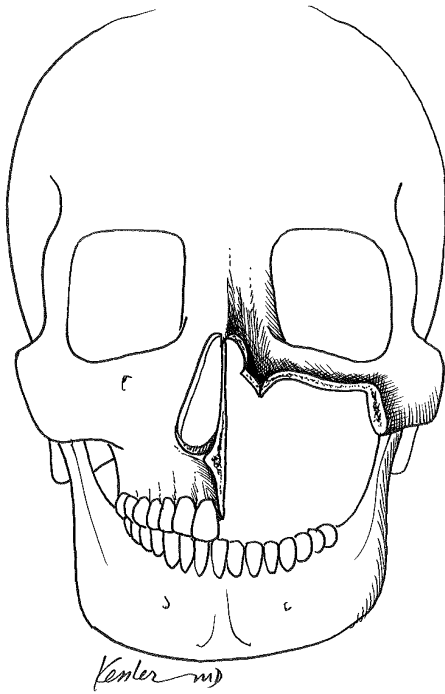


Fig. 3.32 Hemimaxillectomy defect with orbital rim preservation.

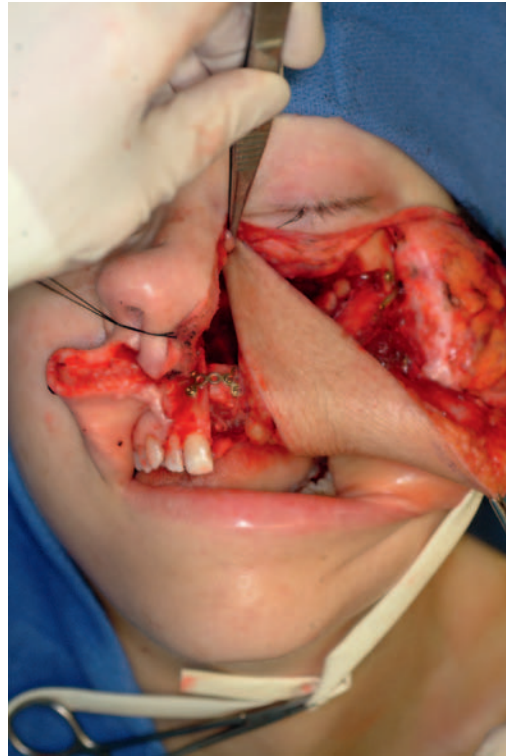


Fig. 3.34 Clinical case. The skin paddle can be de-epithelialized and drawn over the fibular graft to provide structure to the vertical maxillary defect.

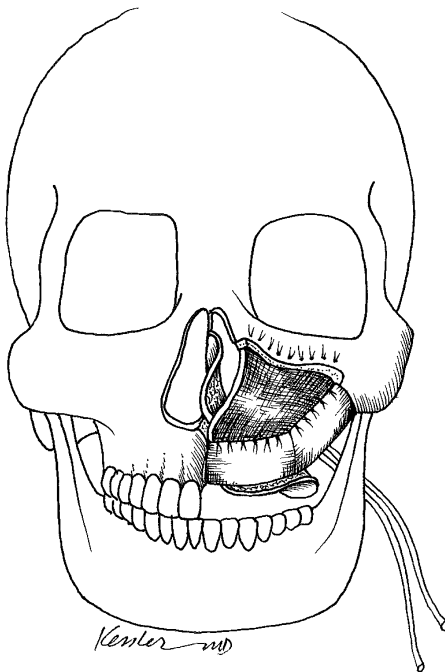


Fig. 3.33 The fibular free flap represents one option for hemimaxillectomy reconstruction when the orbital rim is preserved. The skin paddle is used to reline the palatal defect and then sutured to the remnant of the orbital rim to reconstruct the vertical face of the maxilla. This technique prevents soft tissue contraction and hollowing of the midface.



Fig. 3.35 The skin can also be drawn medially and placed in the vertical maxillary defect to provide bulk.

- ◆ A template can be used to facilitate the design of the flap and identify the sites for osteotomies.
- ◆ The fibula is harvested in a standard fashion with an ellipse of skin that is sufficient to reline the oral palate.
- ◆ Following the harvest, the osteotomies can be completed and the excess bone can be trimmed.
- ◆ The vascular pedicle can be lengthened by dissecting the pedicle and the adjacent periosteum off of the excess bone.
- ◆ The bone graft can be fixed to the remnant medial maxilla and the free edge of the remnant zygoma.
- ◆ The skin paddle should be transposed into the palatal defect to reline the oral palate. The remainder of the skin paddle can be turned upward to reconstruct the lateral nasal wall defect.
- ◆ In those cases where there is a significant vertical defect, Vicryl mesh can be used to bridge the defect between the inferior maxillary defect and the inferior orbital rim.
- ◆ In cases where the nasolacrimal duct is involved in the resection, it is important to perform a dacryocystorhinostomy (DCR) by either marsupializing the lacrimal sac using 5.0 chromic suture, or placing a Silastic lacrimal stent for 6 weeks. Because the sac is usually exposed during the resection, we prefer the former approach.

Patient Selection and Perioperative Management

The ideal patient for this type of reconstruction is one in whom the orbital rim is intact. The scapula or iliac can also be used, but the fibula offers excellent bone stock for osseointegrated implants. Following the reconstruction, we place a Silastic nasal trumpet in the nasal vestibule on the side of the reconstruction. This helps to stent the nasal airway and guide healing. In nonradiated patients, we begin a liquid diet on day 5 and restrict the patient from chewing on the operated side for 6 weeks. In radiated patients, we typically delay a liquid diet until days 7 to 10, depending on the tissue condition.

◆ HEMIMAXILLECTOMY DEFECT WITH ORBITAL RIM RESECTION

Option for Management: Reconstruction Using the Iliac Crest Donor Site

Although the *pure* hemipalatectomy defect without involvement of the zygoma or orbital complex can be managed with either prosthetic rehabilitation or a bone-containing free flap, the unique advantage of free tissue transfer is realized in defects that involve the vertical component of the palatomaxillary complex. Palatomaxillary defects involving the orbital rim and/or the zygomatic arch are particularly difficult to manage prosthetically. Resection of the orbital floor, the orbital rim, or the globe itself represents both a functional and an aesthetic challenge. As discussed earlier, the

bony architecture of the orbit provides support for the globe. Vertical orientation of a bone-containing free flap used in reconstruction of this type of defect provides a bony rim that can serve as a shelf to secure an orbital floor reconstruction, or in the case of an orbital exenteration, provide bone for the placement of implants for a future prosthetic globe. Extensive resections may involve both the lateral orbital rim and the body of the zygoma. In this case, the bone flap can be extended laterally to lend contour to the lateral midface. Restoration of the facial contour provided by the arch of the zygoma, however, will often require the placement of free bone grafts to achieve the optimal cosmetic result.

Surgical Technique and Considerations

- ◆ The vertical dimension associated with the hemimaxillectomy that includes an orbital rim defect is best managed with either a scapular or iliac donor site. This is because only these donor sites offer a bone graft that can be oriented to reconstruct the face of the maxilla, the orbital rim, and the zygoma.
- ◆ The iliac crest donor site provides an excellent source of bone for restoration of the vertical component of the hemimaxillectomy defect. The flap should be harvested with the internal oblique muscle for palatal lining.
- ◆ Prior to harvesting the iliac crest, a vein graft should be harvested in anticipation of the need for a Corlett loop.⁴¹
- ◆ A large segment of iliac crest bone should be harvested from the donor hip ipsilateral to the maxillary defect.
- ◆ Following the harvest, osteotomies should be performed to accommodate the nasal aperture and the orbital rim.
- ◆ Three-point fixation of the bone should be completed at the free edge of the medial maxillary defect, the free edge of the nasal defect, and the lateral zygoma free edge.
- ◆ The internal oblique muscle should be transposed into the oral cavity to reline the palate and the lateral nasal wall.
- ◆ Once the iliac graft has been secured, the Corlett loop should be completed and passed through the subcutaneous tunnel to the facial vessels for the microvascular anastomosis.

Patient Selection and Perioperative Management

The iliac crest–internal oblique donor site presents several challenges. The short vascular pedicle is probably the most significant challenge. When using this donor site, it is best to plan for vein grafts especially if the distal facial vessels are not available. Other limitations include the hearty bone stock, which can be difficult to contour; some have advocated using the split iliac bone graft. Because the internal oblique muscle is typically used to reline the palate, remucosalization can take up to 6 weeks in nonradiated patients and 10 weeks in radiated patients. We recommend nasogastric nutrition for 10 days followed by a liquid diet for 6 to 8 weeks. This provides a suitable period of time to allow for bone union.

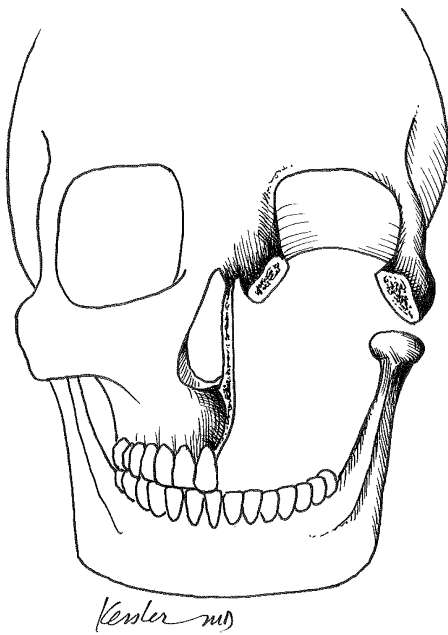


Fig. 3.36 Hemimaxillectomy with orbital rim resection.

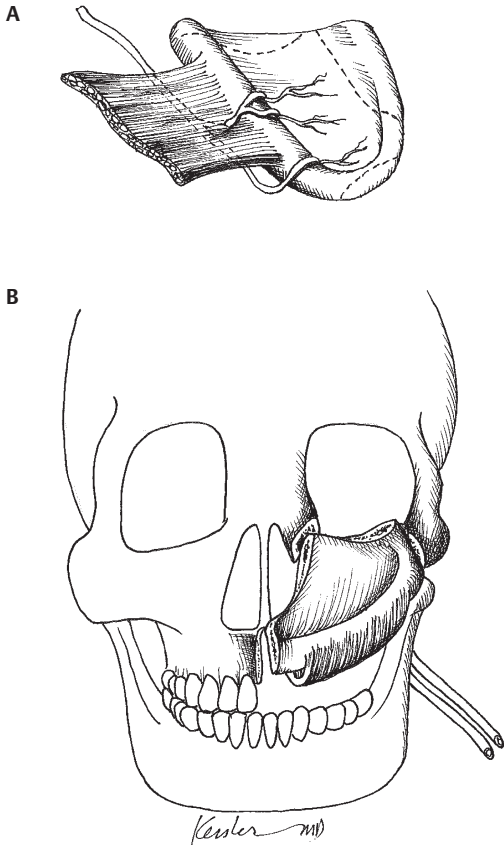


Fig. 3.37 The scapular tip can be harvested and augmented with a reciprocating saw to accommodate the defect. **(A)** The scapula can be oriented vertically and provides an excellent source of bone that can be contoured to accommodate the nasal and orbital rim. **(B)** The teres muscle is used to reline the palate, and the vascular pedicle is drawn into the neck medial to the mandible.

Option for Management: Reconstruction Using the Scapular Donor Site

The scapular donor site represents an option to reconstruct the hemimaxillectomy defect (**Fig. 3.36**). There are a variety of techniques that can be used depending on the extent and position of the defect. The scapular tip or lateral border of the scapula can be oriented vertically to address the alveolus and the vertical component of the defect (**Fig. 3.37**). Often the skin paddle associated with this donor site is thick and less than ideal to reline the palate. As a result, the teres muscle can be harvested and used to reline the palate. Because the teres muscle has no epithelium, it relies on the adjacent mucosa to mucosalize the palate, which typically takes 6 to 8 weeks to complete. The mucosalization process is less reliable in patients who have been previously radiated.

Surgical Technique and Considerations

- ◆ The scapular donor site provides an alternative excellent source of bone for restoration of the vertical component of the hemimaxillectomy defect. The flap should be harvested with the teres muscle or a skin paddle to reline the palate.
- ◆ A vein graft may be necessary for the venous anastomosis; however, a thoracodorsal reverse flow technique can be used to lengthen the arterial pedicle (**Fig. 3.38**).



Fig. 3.38 Clinical case. The facial vessels are dissected and prepared for the microvascular anastomosis.



Fig. 3.39 The scapular tip is oriented vertically and the teres muscle is sutured into the oral cavity to reline the palate.

- ◆ When harvesting the scapular bone, the osteotomies should be extended medially to harvest enough bone to reconstruct the vertical defect (**Fig. 3.39**).
- ◆ Following the harvest, osteotomies should be performed to accommodate the nasal aperture and the orbital rim.
- ◆ Three-point fixation of the bone should be completed at the free edge of the medial maxillary defect, the free edge of the nasal defect, and the lateral zygoma free edge (**Fig. 3.40**).
- ◆ The teres minor muscle or skin paddle can be transposed into the oral cavity to reline the palate and the lateral nasal wall (**Figs. 3.41** and **3.42**).

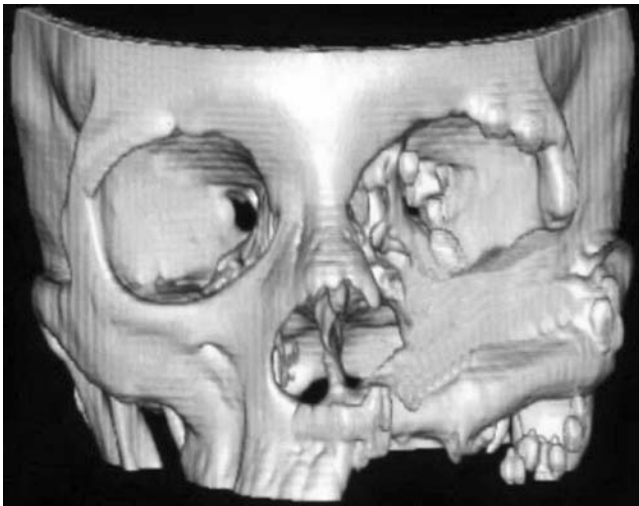


Fig. 3.40 Three-dimensional CT scan demonstrating the scapular bone with three-point fixation. The orbit and nasal cavities have been contoured.

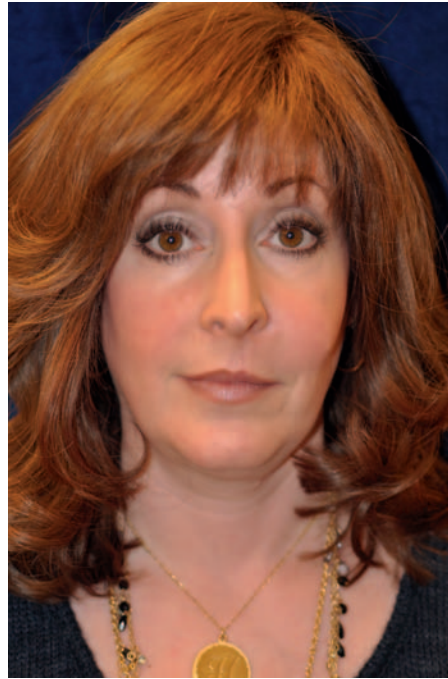


Fig. 3.41 Eight months postoperatively, the cosmetic and functional results are excellent.

Patient Selection and Perioperative Management

The scapular donor site provides an excellent source of bone for the hemimaxillectomy defect with orbital rim resection. The challenge with this donor site is the thickness of the skin paddle. Depending on the body habitus of the patient, the skin paddle may be too thick to appropriately reline the palate. In such situations, we advocate using the teres muscle, similar to the method described when using the internal oblique muscle for the iliac crest donor site. Although the scapular donor site cannot be harvested using a two-team approach, we find this donor site ideal for the hemimaxillectomy defect with orbital rim resection.



Fig. 3.42 Oral-dental rehabilitation. The teres muscle has remucosalized.

◆ THE TOTAL MAXILLECTOMY DEFECT

The total palatomaxillary defect renders patients with essentially no remaining functional palate. Commonly, these defects are associated with very little residual maxillary bone or the appropriate bony undercuts to support a prosthesis. Similarly, patients may sustain resection of the orbital floor, the body of the zygoma, or the nasomaxillary buttress, making midface reconstruction and orodental rehabilitation a challenging task. As a result, this group of patients represents the most difficult group to rehabilitate, but also the most in need. A variety of soft tissue and composite free flaps have been applied to the reconstruction of the total palatomaxillary defect including scapula,⁹ fibula,⁴² radial forearm,⁴³ rectus abdominis,²² iliac crest,⁴⁴ and latissimus dorsi.¹¹ The use of soft tissue flaps to partition the oral and nasal cavities can serve to improve speech; however, it has only been since the routine application of osseointegrated implants for orodental rehabilitation that the advantages of bone-containing composite flaps have been realized. In the author's experience, a bone-containing free flap in conjunction with careful preoperative planning with an experienced prosthodontist can yield excellent postoperative functional results for this daunting defect.

In 1999, Brown reviewed the functional outcome of a series of 45 maxillectomy patients.⁴⁵ In this series, Brown acknowledged the functional deficit associated with near-total and total palatotomy defects and recognized that the problems associated with successful obturation mounted as the vertical components of the resection increased. He found that failure to reconstruct these patients with a bone-containing free flap left patients unable to achieve adequate oral rehabilitation. Similar findings were described by Triana et al, who reported a multicenter series of 51 palatomaxillary free

flap reconstructions for a variety of palatomaxillary defects.⁴⁶ Twelve patients in this series sustained "subtotal or total" defects of the palatomaxillary complex. The functional results in this series were not stratified based on the extent of the defect; however, the authors point out that reconstruction of extensive subtotal and total palatomaxillary defects is best achieved with a bone-containing free flap. Our experience in treating total palatomaxillary defects supports prior work suggesting that prosthetic reconstruction does not offer this group of patients an optimal form of orodental rehabilitation or cosmetic restoration of the midface. Furthermore, obturation can be exceedingly difficult after the inevitable course of radiotherapy for advanced lesion of the palatomaxillary complex. Although successful rehabilitation of this defect has been achieved with soft tissue reconstruction,⁴⁷ it is clear that optimal rehabilitation of this patient group is dependent on more than just separating the oral and nasal cavities. The presence of vascularized bone confers a functional advantage that cannot be achieved with either prosthetic or soft tissue reconstruction alone.

Option for Management: Reconstruction Using the Fibular Donor Site

Total palatomaxillary defect can be reconstructed using either a fibula or the horizontally oriented iliac crest–internal oblique. The fibula offers an excellent segment of bone that can be oriented horizontally to reconstruct the maxillary alveolus in cases with a limited vertical component (**Fig. 3.43**). The proximal and distal ends of the bone graft can be secured to the remaining zygoma, and the skin paddle can be rotated to reline the palatal surface and the nasal floor (**Fig. 3.44**).

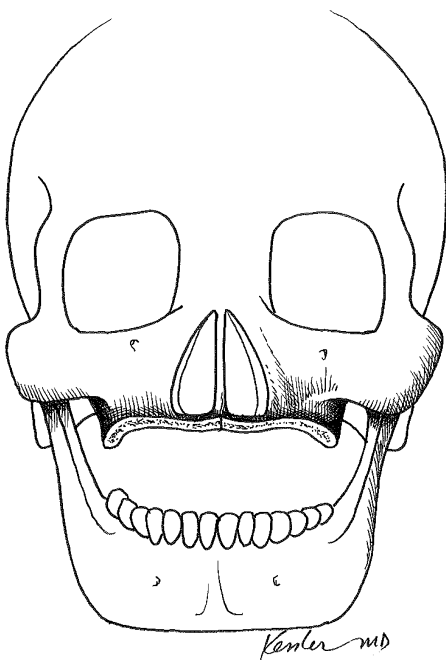


Fig. 3.43 The total maxillectomy defect.

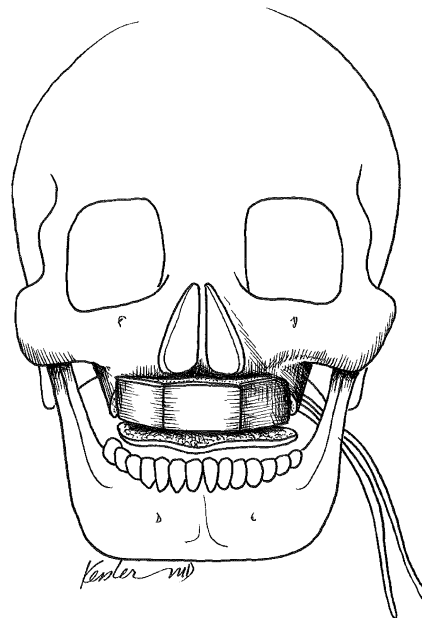


Fig. 3.44 The fibular bone can be contoured to the defect to provide bone for the palatal arch and skin to reline the palate and nasal cavity.

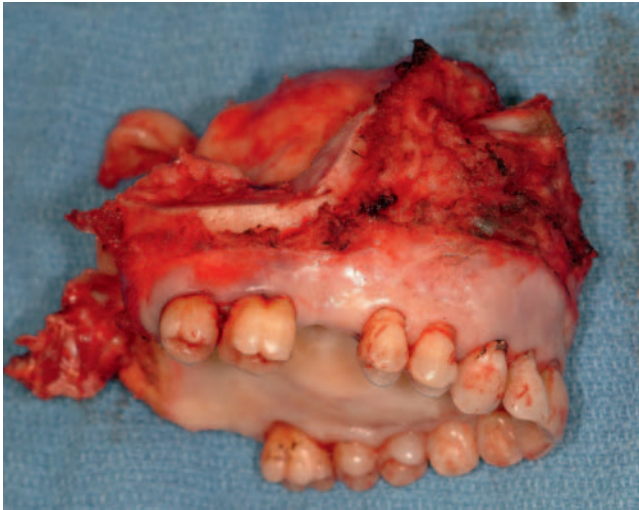


Fig. 3.45 Clinical case. Total maxillectomy.

Surgical Technique and Considerations

- ◆ The complete infrastructure defect requires palatal lining and nasal floor lining. The skin paddle should be designed to sandwich the fibular bone and line both the palate and nasal cavity with skin (**Fig. 3.45**).
- ◆ Once the defect is established, a subcutaneous tunnel medial to the mandible should be completed to pass the vascular tunnel to the donor vessels in the neck.
- ◆ Prior to making the necessary osteotomies and fixing the bone to the upper jaw remnant, the vascular pedicle should be dissected from the fibular bone to lengthen the vascular pedicle (**Fig. 3.46**).
- ◆ The bone can be fixed to the free margin of the native maxilla with titanium miniplates (**Fig. 3.47**).
- ◆ The skin paddle should be rotated into the oral cavity to reline the oral palatal defect and into the nasal defect to reline the floor of the nose. The intervening segment of skin should be de-epithelialized.

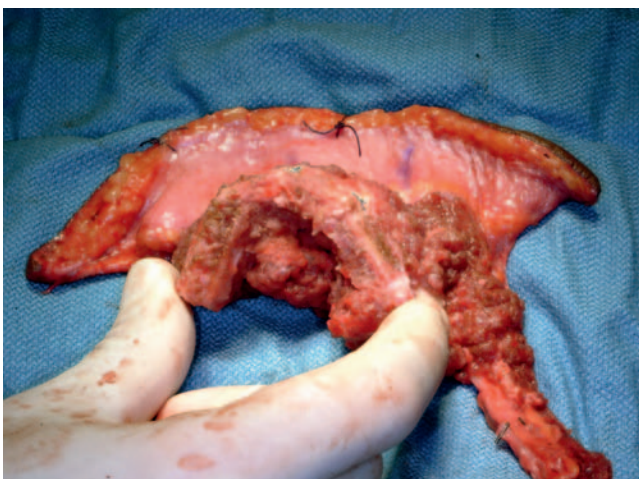


Fig. 3.46 The fibular bone is contoured to replicate the native maxillary arch.



Fig. 3.47 The bone is fixated and the skin paddle is placed into the nasal cavity and the oral palate with a segment that is de-epithelialized to accommodate the lip.

- ◆ Vicryl suture is used to suture the fibular skin paddle to the free edge of the native palatal mucosa.
- ◆ The microvascular anastomosis is then completed following the fixation of the bone graft to the upper jaw.
- ◆ The bone projection will establish a satisfactory cosmetic contour (**Fig. 3.48**).
- ◆ The skin paddle acts to reline the palate (**Fig. 3.49**).

Patient Selection and Perioperative Management

Postoperatively, the Silastic nasal trumpets are placed into the nares for 5 days to stent the nasal airway from the skin paddle of the nasal floor. To optimize bone healing, we recommend that patients refrain from mastication for 6 weeks. Patients are fed with a nasogastric tube for 7 days. After 7 days, the patient is advanced to an oral liquid diet for 6 weeks, and thereafter the patients are advanced to a soft diet.

Although the fibular donor site is appropriate for most maxillectomy defects, in rare cases the bone height may not be sufficient to address defects involving the orbital rim or body of the zygoma. An alternative to the fibular donor site is the iliac crest–internal oblique donor site. The iliac bone graft can be oriented horizontally as described by Brown et al.⁴⁵ The tripartite design of this flap is unique in that the muscle can be used to reline the palatal surface area, and the skin paddle can be used to resurface the nasal floor. There are several shortcomings of this donor site, including the

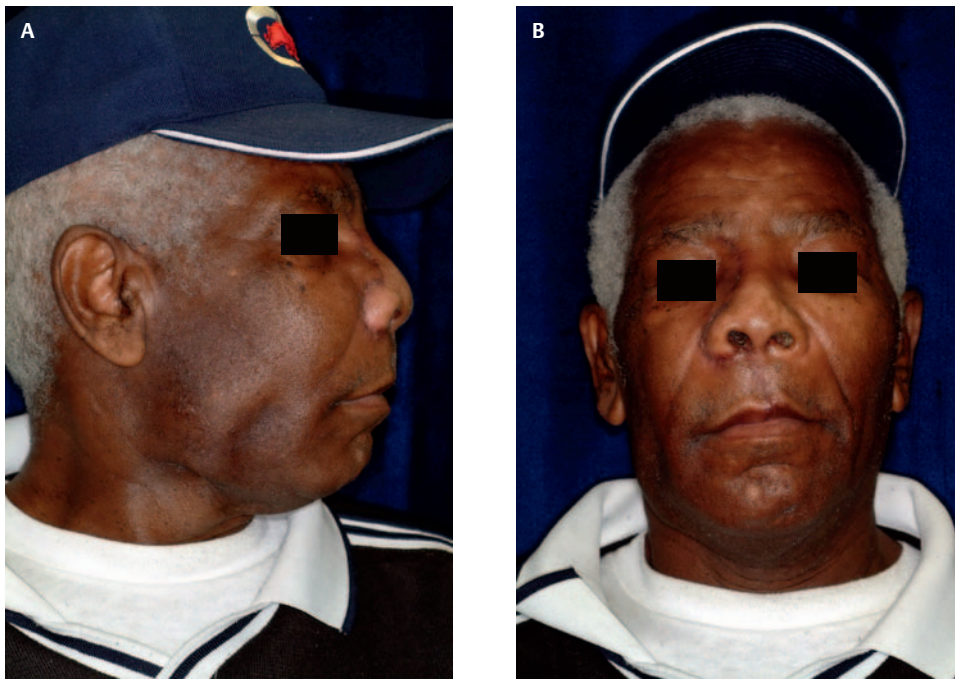


Fig. 3.48 Postoperatively, the patient has excellent midface contour. Side view (A) and frontal view (B).

short vascular pedicle and donor-site morbidity. The iliac crest also tends to be more difficult to work with because in spite of contouring osteotomies, the bone graft can be difficult to conform to the defect.

rehabilitation can provide an excellent combination to achieve an optimal functional and aesthetic result (**Fig. 3.51**). An extensive defect of the maxilla that involves the orbit and globe can represent a reconstructive challenge. In such a

◆ ADJUNCTIVE PROCEDURES FOR MAXILLARY RECONSTRUCTION

Prosthetic Rehabilitation

In some cases, tissue reconstruction is limited in the ability to restore complex anatomy such as the globe (**Fig. 3.50**). A combination of soft tissue, hard tissue, and prosthetic



Fig. 3.49 The oral skin paddle provides a permanent restoration of the palate.



Fig. 3.50 Clinical case. Extensive defect of the nasal orbital complex with a palatal defect.



Fig. 3.51 Initial reconstruction with a scapular free flap to reline the maxilla, orbit, and palate.

case, the addition of bone and soft tissue provides the tissue necessary to partition the nasal cavity and the oral cavity and the scaffold necessary for anchoring the prosthesis (**Figs. 3.52** and **3.53**).



Fig. 3.53 Oral cavity reconstruction provides permanent separation between the oral and nasal cavities. The patient is able to retain a denture.

◆ CONCLUSION

Arguably, palatomaxillary reconstruction represents the most challenging aspect of head and neck reconstruction. This technique requires an appreciation of the biomechanics of the upper jaw, the cosmetic form of the upper jaw, and the soft tissue palatal defect. Additionally, bony fixation and pedicle geometry can be a challenge. A preoperative estimate of the defect can be helpful in surgical planning; however, it is important to hold in reserve a variety of reconstructive tools in the event that the defect is different from what was



Fig. 3.52 Following debulking and contouring, the patient is fit with a prosthesis that is anchored with osseointegrated implants. Frontal view (**A**) and side view (**B**).

anticipated. Irrespective of the defect, the goal should be to achieve a reconstruction that does not require prosthetic obturation and provides enough bone for orodental rehabilitation.

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4

Cheek and Neck Reconstruction

Stephen M. Weber, Mark K. Wax, and Eric M. Genden

Defects of the cheek may range from a superficial cutaneous defect to a through-and-through composite defect. Because of the impact on both aesthetics and function, defects of the cheek represent one of the most challenging areas of reconstruction. The cheek plays an important role both in aesthetics and in the physiology of articulation of speech and swallowing. Defects of this important anatomic area often result in an impairment of these functions. And although the functional component of the cheek is important, the contribution to aesthetics and self-perception cannot be understated. The facial deformity associated with a cheek defect can result in significant social repercussions including self-imposed isolation, depression, and an overall diminished quality of life. For these reasons, reconstruction of the cheek and its related structures requires a thoughtful approach that starts with an appreciation of the anatomy of this region.

◆ RELEVANT ANATOMY

The cheek extends from the inferior border of the mandible to the inferior orbital rim. Medially, it arises at the lateral aspect of the nasolabial line and extends to the preauricular area. Considered as a distinct anatomic subunit, the cheek is composed of skin, subcutaneous tissue, parotid gland, facial musculature, and a mucosal lining from the inside of the oral cavity. The texture of the skin differs depending on the location. The preauricular skin is pale and thin, whereas the skin over the malar area can be thick and more richly colored. The skin changes with age, generally taking on a thinner epidermis. Immediately deep to the skin of the cheek is the superficial musculoaponeurotic system (SMAS). This layer is continuous with the platysma muscle from the neck and extends superficial to the deeper visceral structures of the face. Beneath this layer lies the parotid gland in the preauricular area. The anterior two thirds of the cheek marks the area where the facial nerve branches as they exit the parotid gland along with the superficial layer of facial muscles. The

buccal fat pad and inner cheek buccal mucosa lie anterior and deep to the masseter muscle. The anatomic structures involved in the defect will predicate the optimal approach to reconstruction.

Sensory supply to the cheek is provided primarily by the second and third divisions of the trigeminal nerve. There is a marked degree of overlap, and should one of these sensory nerves be severed, growth from the adjacent dermatome is common. The superficial facial muscles are supplied by the seventh cranial nerve as it exits the parotid gland.

Finally, the arterial supply comes mainly through the external carotid artery via the facial artery. Venous drainage is through the anterior facial vein into the internal jugular venous system. The vascular supply is richly anastomotic with connections from deeper structures and from the contra lateral supply. Ligation of major vessels, such as the facial artery bilaterally, does not have a detrimental effect on healing of this structure as there is also retrograde supply through the angular artery adjacent to the lateral nasal bone.

◆ CHEEK RECONSTRUCTION: AESTHETICS AND FUNCTIONAL CONSIDERATIONS

Aesthetically, the facial skin and, in particular, the cheek contribute a great deal to self-perception and the way in which the world perceives us. Because of the cheek's location on the face, a major defect in this area draws the eye and becomes a center of aesthetic focus. When this defect is coupled with a facial paralysis, the cosmetic impact can be devastating. The most important aesthetic considerations should be the color and texture of the facial skin and preserving facial symmetry. Matching the color and texture of the cheek skin is a rather significant challenge because there are few donor sites that provide a similar match. Commonly, distant donor sites are used for extensive defects; however, this can result in a suboptimal cosmetic result. Although donor sites such as the radial forearm and anterolateral thigh

can provide coverage for extensive defects, submental and posterior scalp donor skin may provide a better match. Thoughtful attention to donor-site planning can help in achieving a good result.

In addition to the aesthetic implications of a cheek defect, the cheek and its musculature also assist in articulation of speech and the oral phase of swallowing. The muscular tone of the buccinator within the cheek aids in the enunciation of words and oral deglutition. When this dynamic is compromised, oral competency may be hindered, resulting in drooling or food trapping. In contrast, if the buccal region is stiff, trismus may ensue. This too can impact swallowing and speech. The ability to open one's mouth partially depends on the integrity of the internal lining of the buccal mucosa. We usually attribute trismus to the muscles of mastication. However, patients who undergo a through-and-through cheek resection involving the buccal mucosa require a reconstructive option that does not lead to scar contractures, which can result in trismus.

Finally, achieving a cosmetically acceptable, functional, and durable reconstruction requires a careful assessment of the defect, the goals of the reconstruction, and an understanding of the challenges unique to cheek reconstruction. One unique challenge related to cheek reconstruction is the tendency for flaps to pull or drag on the crucial structures such as the lower eyelid or oral commissure. Because of the location of the cheek relative to the eye, mouth, and nose, the weight of a flap or the contractures associated with healing can lead to unintended problems such as lower lid ectropion or oral commissure distortion that can functionally impair a patient. For all the reasons stated, cheek reconstruction is considered a unique challenge to the head and neck surgeon.

◆ CLASSIFICATION OF CHEEK DEFECTS

There is no accepted standard for classifying defects of the cheek, although it is helpful to classify them. Reconstruction of the cheek can be classified in many different ways according to size, location, depth, and the functional deficit. For the purposes of addressing major defects of the cheek, we have organized reconstructive options according to cutaneous defects, defects involving the skin and facial musculature, through-and-through defects, and through-and-through composite defects.

◆ THE EXTENSIVE CUTANEOUS DEFECT

Superficial lesions of the cheek may result from malignancy, trauma, or a variety of congenital or acquired deformities. Superficial spreading cutaneous malignancy such as that seen with basal cell carcinoma (BCC) can result in extensive cutaneous defects that leave the underlying facial nerve and mimetic musculature intact. Most tumors of the cheeks are detected in an early stage, and therefore reconstruction can be achieved with primary closure or a variety of rotation advancement flaps (Figs. 4.1, 4.2, and 4.3). Bilobed



Fig. 4.1 Clinical case. This represents a relatively small defect of the cheek. The defect is too large for primary closure even with aggressive undermining.

melolabial and V-Y advancement flaps have been utilized with excellent results. The reconstructive technique of choice is often predicated on the surgeon's personal experience. As patients age, tissue redundancy increases, making local flaps more available for intermediate-sized defects. As defects



Fig. 4.2 A melolabial and V-Y advancement flap is raised and the tissue is advanced.



Fig. 4.3 The V-Y advancement flap offers excellent tissue color and texture match.

become larger, however, the option of local advancement flaps diminishes, and healing by secondary intention, skin grafting, regional flaps, and free tissue transfer become the only options available. In general, healing by secondary intention and split-thickness skin grafts result in contractures and unfavorable scarring that is unpredictable. These techniques should be saved for critically ill patients who could not tolerate a prolonged operative procedure.

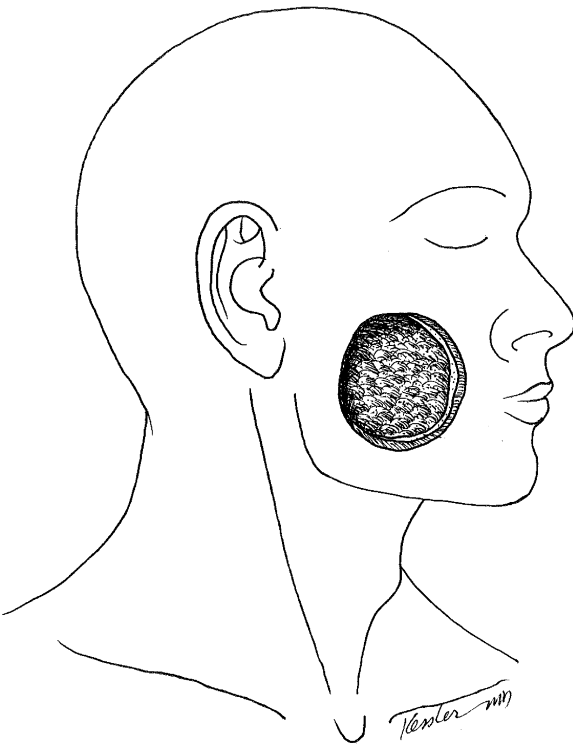


Fig. 4.4 A large cutaneous cheek defect.

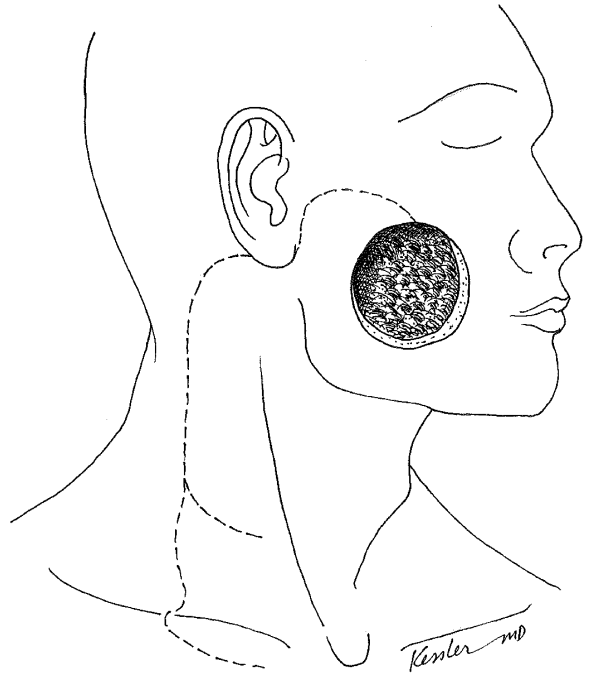


Fig. 4.5 The cervicofacial flap can be planned with a midneck or infraclavicular back-cut to provide rotation of the cervicofacial skin.

Option for Management: Cervicofacial Advancement Flap (Figs. 4.4, 4.5, and 4.6)

Although the cervicofacial flap is one of the oldest techniques used for cheek reconstruction, it is also one of the best

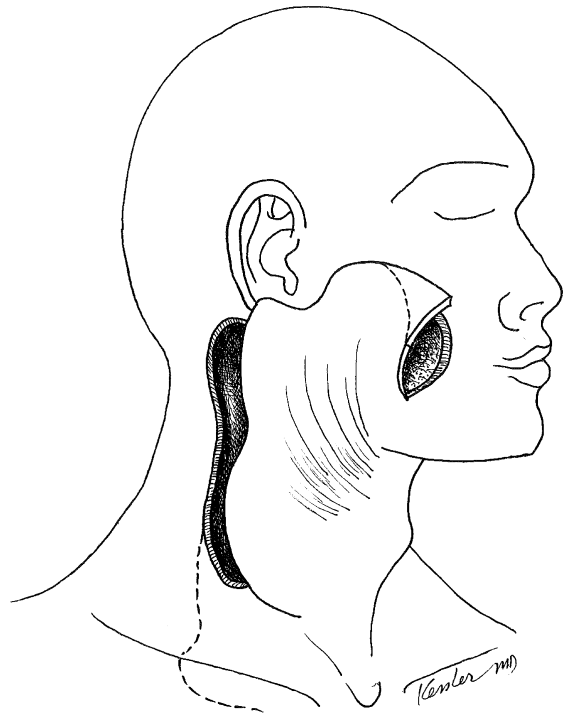


Fig. 4.6 The cervicofacial advancement flap is raised in a sub-superficial musculoaponeurotic system (SMAS) and subplatysmal plane to preserve the blood supply. Extensive undermining and dissection is required to close the defect without tension.



Fig. 4.7 Clinical case. An extensive defect of the cheek.

techniques for the management of superficial cutaneous defects for the cheek. There is no better match for color and texture of the cheek than the skin of the adjacent neck. An understanding of the vascular anatomy of the cervicofacial advancement flap is important when designing and determining the reliability of the flap.

Surgical Technique and Considerations (Figs. 4.7 and 4.8)

- ◆ Cervicofacial rotation advancement flaps may be based anteriorly or posteriorly.
- ◆ The flap can be elevated in the subcutaneous or deep plane, deep to the SMAS and platysma muscle.
- ◆ Anterior based flaps are most useful for posterior and large anterior defects. The arterial supply is from the facial and submental arteries.
- ◆ The incision is designed to be placed along the superior boundary of the cheek, down the preauricular crease, and around the earlobe toward the occipital hairline.
- ◆ If more rotation is necessary, a back-cut can be placed medially in a cervical crease or extending the incision more inferior to the level of the clavicle prior to back-cutting.
- ◆ For very large defects, the incision may be extended in the subplatysmal plane down to the midchest as a



Fig. 4.8 The cervicofacial advancement flap is rotated and advanced to restore the cheek defect. It is important to minimize the tension on the superior aspect of the closure to prevent draw on the lower eye lid. The cervicofacial advancement flap is designed so that rotation of the flap provides coverage of the defect. The flap is sutured into place with fine nylon. There is very little tension on the closure.

cervicopectoral flap. This will capture additional arterial supply arising from internal mammary perforators.

Patient Selection and Perioperative Management

The cervicofacial advancement flap is ideal for a patient with a small to moderate-sized defect that involves the cutaneous tissue. Defects that involve the facial musculature can be managed with a cervicofacial advancement flap; however, the loss of muscle and subcutaneous tissue will result in a hollowing of the cheek.

Postoperatively, it should be stressed that the patient should not use tobacco or even be subjected to second-hand smoke, because it may compromise the blood flow to the flap. When a large flap is used, it is important that the wound be well drained so that the suture line is not stressed. In part, this requires that the flap be raised with enough laxity to minimize tension at the distal suture line.

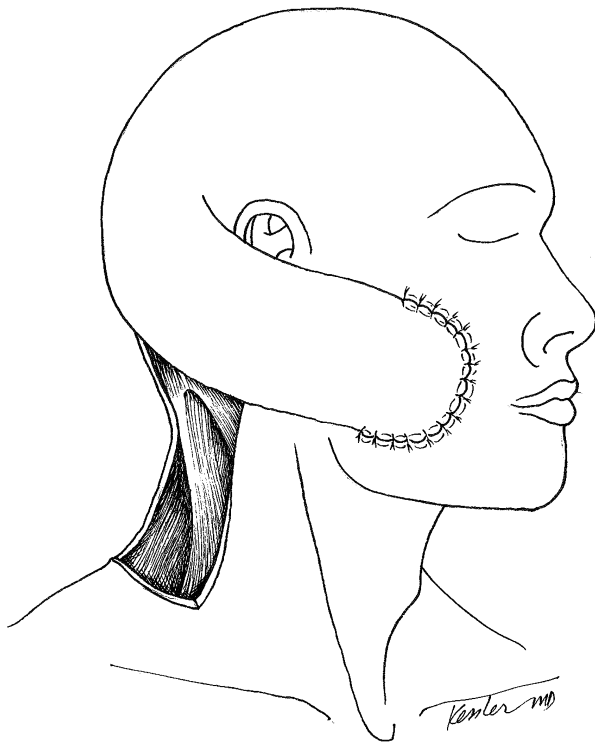


Fig. 4.9 The posterior scalping flap is raised and rotated into the cheek defect. The flap is left in place for 3 weeks.

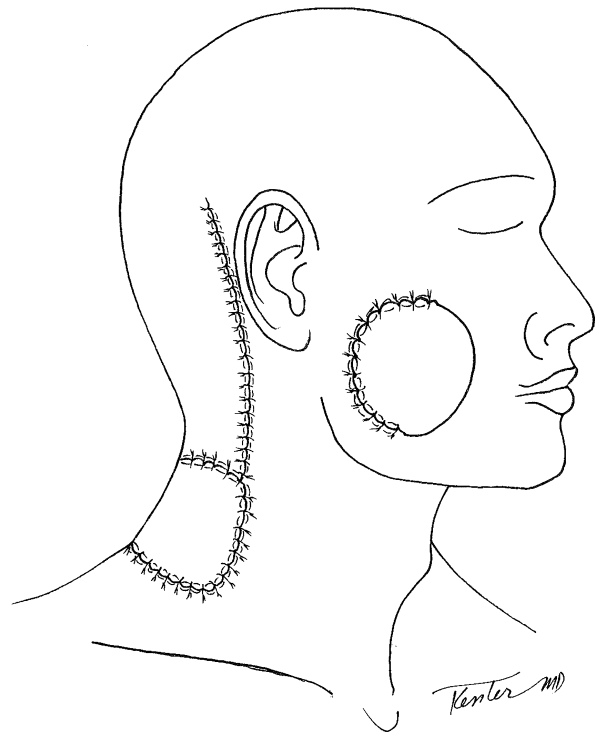


Fig. 4.10 After 3 weeks the flap is divided and the scalp carrier is returned to the posterior scalp. The donor site is managed with a split-thickness skin graft.

Option for Management: Posterior Scalping Flap (Figs. 4.9 and 4.10)

Arena¹ has been credited with describing the posterior scalping flap as a two-stage technique for managing defects of the cheek and midface. The posterior scalping flap accomplishes many of the objectives of the anterior scalping flap and forehead flap without the disfigurement of a forehead scar. The donor site, in the nape of the neck, is easily camouflaged, particularly in women with long hair. The donor skin derived from the nape of the neck is an excellent color and texture match for the cheek. The shortcoming of this technique is that it is a staged procedure requiring patience and understanding on behalf of the patient and his/her caregivers. The details related to raising the posterior scalping flap can be found elsewhere.^{1,2}

Surgical Technique and Considerations

- ◆ The patient's cheek defect is first measured (**Fig. 4.11**).
- ◆ The area of non-hair-bearing posterior neck skin that will be transferred to the face is marked.
- ◆ A vertical midline incision is made from the vertex to the posterior midneck. The length of the incision can be extended in a caudal direction to obtain greater distal flap length. A second, postauricular incision is then made, parallel to the midline incision, along the anterior border of the trapezius muscle.
- ◆ The two vertical incisions are then connected horizontally at the base of the neck and the flap is



Fig. 4.11 Clinical case. The defect involves the facial skin, the facial musculature, and the buccal mucosa. This is a classic through-and-through defect of the cheek.



Fig. 4.12 The posterior scalping flap is designed with enough skin to reach the distal aspect of the cheek defect. The posterior scalping flap is raised first and permitted to profuse to ensure adequate blood supply to the distal flap.

elevated, including skin, subcutaneous fat, and the fascia overlying the trapezius and splenius muscles (**Fig. 4.12**).

- Once the posterior scalping flap is raised, if facial reanimation or an intraoral repair is required, this can be performed (**Fig. 4.13**).



Fig. 4.13 The gracilis flap is positioned into the defect, the intraoral defect is reconstructed, and the gracilis muscle is revascularized with the facial vessels. The nerve anastomosis is completed with microvascular anastomosis with the distal remnant of the facial nerve or a cross-facial nerve graft.

- The flap, pedicled superiorly, is then rotated anteriorly, over the ear, and sutured into the recipient site. The vertical midline incision can be extended further superiorly to achieve greater arc of rotation of the flap into the midface.
- A split-thickness skin graft is used to resurface the donor site.
- Three weeks postoperatively, the pedicle is transected, and that portion of the flap that is not used in the reconstruction is returned to the posterior neck (**Fig. 4.14**).
- The long-term result provides a good color match and functional result (**Fig. 4.15**). The donor site skin graft is well hidden (**Fig. 4.16**).

Patient Selection and Perioperative Management

The indications for the approach include medium-sized to large cutaneous defects of the cheek. In select cases of secondary reconstruction, a tissue expander can be used for extensive midfacial defects. This increases the size of the skin available for transfer as well as aids in primary closure of the donor site. Because this flap requires a staged approach with a 3- to 4-week interim period, it is essential that the patient and his/her caregivers are aware of the wound care and patience that are required to endure the perioperative period. The blood supply to the posterior scalping flap is derived from the superficial temporal, supraorbital, and supratrochlear arteries. Therefore, compromise of these vessels is a contraindication to using this technique.

Postoperatively, the donor site can be managed with a nonadhesive dressing placed superiorly, whereas the inferior area can be skin grafted. It is essential that the patient not use tobacco because this may compromise blood flow to the distal area of the flap. It is also important that the patient sleep in the decubitus position so as not to place pressure



Fig. 4.14 The final step involves rotation and suturing of the posterior scalping into the cheek defect.



Fig. 4.15 Two-year postoperative result demonstrates an acceptable functional and cosmetic result.

on the vertex of the scalp, which could lead to vascular compromise. After 3 to 4 weeks, the skin flap carrier can be transected and returned to the posterior neck.

Option for Management: Submental Island Flap (Figs. 4.17, 4.18, and 4.19)

The submental island flap was first described by Martin et al³ in 1993. Elevating this flap is relatively simple, and the technique is reliable. The donor site can be closed primarily



Fig. 4.16 A skin graft is used to resurface the donor site.

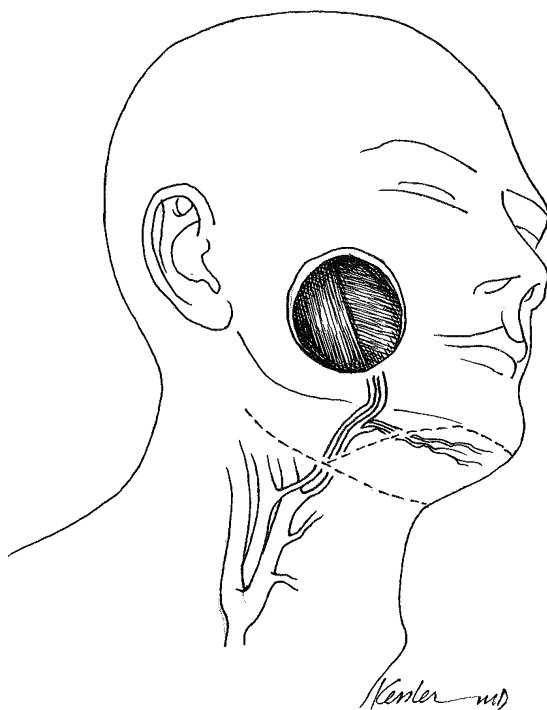


Fig. 4.17 The submental island flap provides an excellent source of tissue that matches the cheek skin in color and texture. The blood supply of the flap is based on the submental artery and vein. The flap should be designed with the donor site in mind. An elliptical flap design facilitates the donor-site closure.

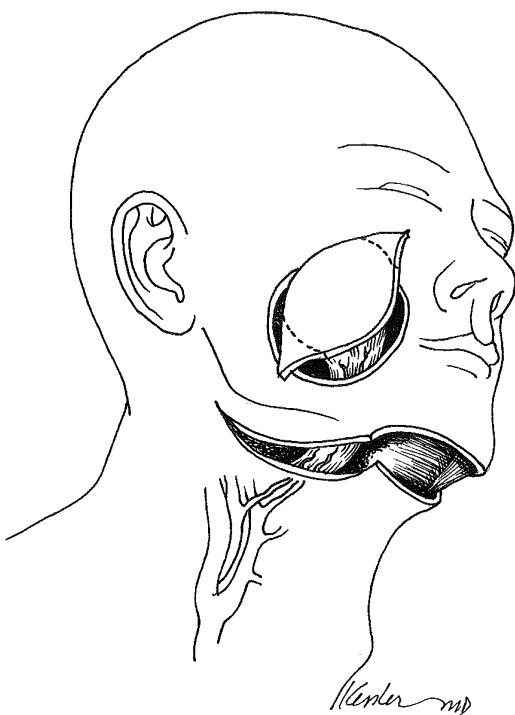


Fig. 4.18 The flap is passed through a subcutaneous tunnel to the recipient site. The excess flap can be trimmed to accommodate the defect.

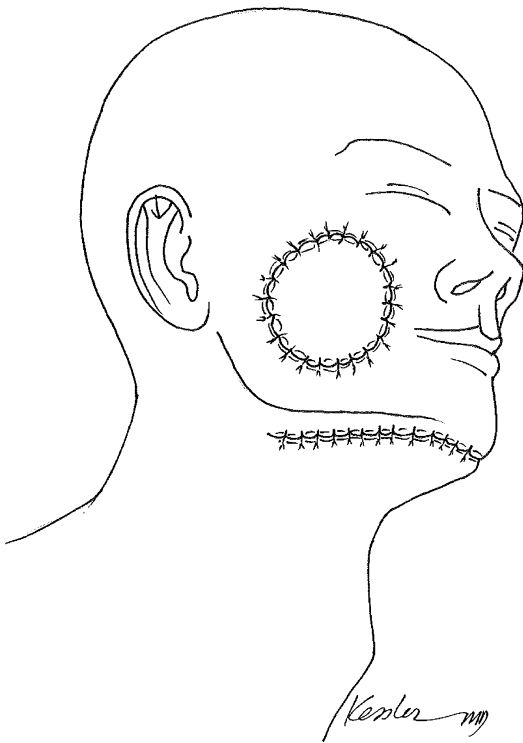


Fig. 4.19 The donor site can be closed primarily.

and easily concealed in the submentum of the neck. It has a wide variety of applications and can be raised as a cutaneous, myocutaneous, fasciocutaneous, or osteocutaneous flap. The donor tissue can be used for coverage of perioral, intraoral, and facial defects. The submental island flap provides excellent color and texture match to facial skin. This donor site is an excellent choice for management of the cheek defect. Several techniques have been described to raise the flap, and these can be found elsewhere.³⁻⁵

Surgical Technique and Considerations

- ◆ The submental island flap is an axial patterned flap based on the submental artery. The submental artery is a well-defined and consistent branch of the facial artery (**Fig. 4.20**).
- ◆ The zone of perfusion allows a large flap to be raised from mandibular angle to angle, with the width determined by the laxity of the neck skin allowing primary closure, affording a flap as large as 18 cm (length) × 7 cm (width).
- ◆ The vascular pedicle length can range up to 8 cm, providing an arc of rotation extending from the medial canthus to the zygomatic arch.
- ◆ When extra length is necessary, division of the facial vessels distal to the origin of the submental artery will provide an additional 1 to 2 cm of length (**Fig. 4.21**).
- ◆ The defect should be measured and the flap can be designed in an elliptical fashion according to the requirements of the defect.



Fig. 4.20 Clinical case. A cutaneous defect involving the cheek and the oral commissure.

- ◆ The upper limit of the flap is drawn within the mandibular margin at least 5 mm behind the ramus, from angle to angle to avoid a visible scar and prevent inferior lip ptosis.
- ◆ The lower border and flap width is determined by assessing the laxity of the submental skin by pinching the submental skin island to be harvested.
- ◆ After raising the flap, a subcutaneous tunnel can be made either medial or lateral to the mandible to gain access to the defect. Superficial defects are best managed by tunneling the pedicle lateral to the mandible.



Fig. 4.21 The submental island flap is harvested and rotated into the defect, and the donor site is closed primarily.



Fig. 4.22 The skin paddle provides an excellent color match to the cheek.

- ◆ The donor site can be closed primarily if the inferior aspect of the adjacent neck skin is elevated and transposed superiorly (**Fig. 4.22**).
- ◆ The long-term results provide a good color match (**Fig. 4.23**).

Patient Selection and Perioperative Management

The submental island flap can be applied to almost any defect of the facial skin extending to the level of the zygoma



Fig. 4.23 One-year follow-up demonstrates excellent color and texture match.



Fig. 4.24 Clinical case. The submental island flap can also be applied to defects of the chin. The donor skin is harvested as an ellipse to facilitate donor-site closure.

superiorly. The two relative contraindications to using the submental island flap are a history of neck radiation and submental (level I) regional metastatic disease. Radiation may compromise donor-site healing, and regional metastatic disease can raise the risk of implanting metastatic lymph nodes into the cheek.



Fig. 4.25 The flap is raised and given time to perfuse before rotating it into the recipient site.



Fig. 4.26 The vascular pedicle is dissected with soft tissue to improve vascularity to the distal flap.

Postoperatively, the submental drain should be left in place for 2 to 3 days and a compressive dressing can be applied; however, the pedicle should be not be compressed.

The submental island flap provides an excellent source of tissue for the chin as well as the cheek (**Fig. 4.24**). Defects of the chin are often difficult to manage without free tissue transfer; however, the color results are often poor. In contrast, the submental island flap provides a suitable color and texture match (**Figs. 4.25, 4.26, and 4.27**). The long-term results are durable and reliable (**Fig. 4.28**).



Fig. 4.27 The flap is sutured into the recipient site.



Fig. 4.28 One-year follow-up demonstrates the excellent tissue match and cosmetic result.

◆ DEFECTS INVOLVING THE SKIN AND FACIAL MUSCLES

Lesions involving the cheek muscles may result from extensive skin cancer that has eroded into the deep tissues of the cheek or tumors arising from the parotid gland that have invaded the overlying skin. Tumors of the skin that erode through the skin into the subcutaneous tissue and facial muscles often require both cutaneous reconstruction and facial reanimation. This can be accomplished in a variety of ways depending on the extent of the defect and the goals of the patient. Any of the techniques previously described for reconstruction of the extensive cutaneous defect (cervicofacial advancement flap, submental island flap, or the posterior scalping flap) can be combined with a static or dynamic facial reanimation procedure to achieve a suitable result.

Option for Management: Posterior Scalping Flap and Gracilis Flap (**Figs. 4.29 and 4.30**)

Although the posterior scalping flap provides a source of excellent tissue color and texture match for cheek reconstruction, alone it does not provide the muscle necessary for facial reanimation. The technique for posterior scalping flap, discussed previously, provides outer cheek lining (**Figs. 4.11, 4.12, 4.13, 4.14, 4.15, and 4.16**), but must be combined with another flap to achieve intraoral lining. However, when combined with either static tensor fascia lata suspension, dynamic temporalis muscle interposition, or gracilis free flap reanimation, the combination of techniques can provide an excellent result.

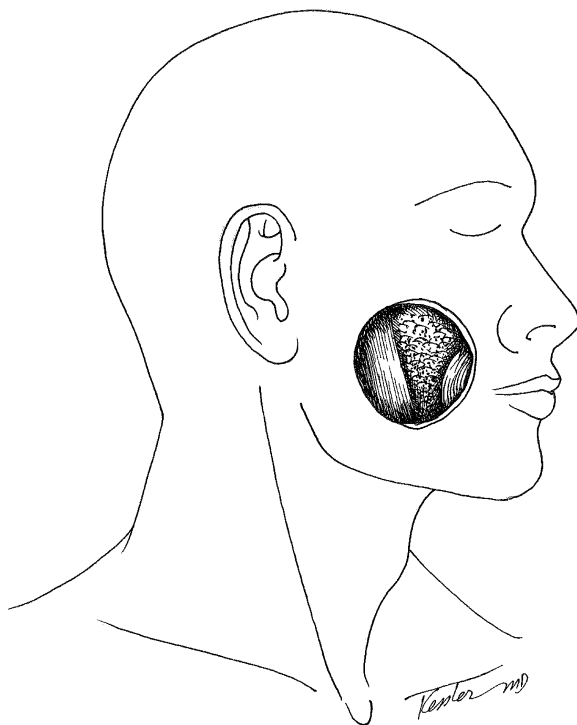


Fig. 4.29 A defect of the cheek involving the facial musculature.

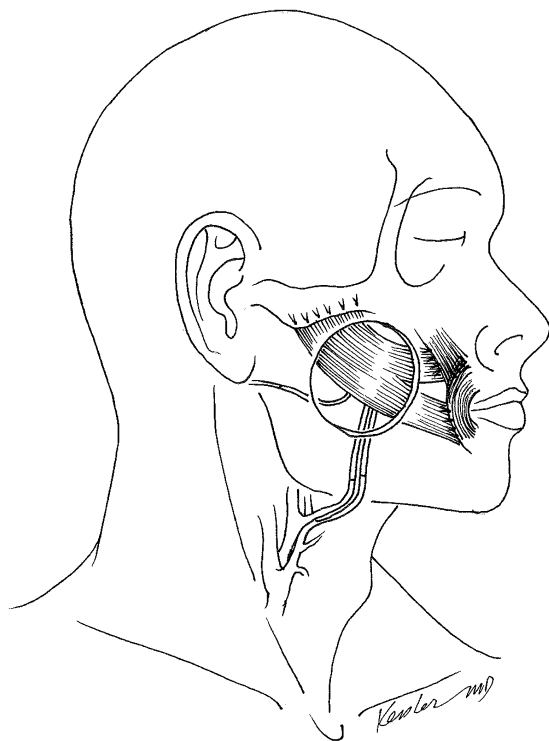


Fig. 4.30 The gracilis flap provides an excellent source of innervated muscle to restore facial reanimation. In those cases where the facial nerve stump is available, a direct anastomosis to the obturator nerve can be performed and the vascular anastomosis can be achieved with the facial vessels.

Surgical Technique and Considerations

- ◆ The posterior scalp flap should be planned to accommodate the defect (**Fig. 4.17**) and raised initially so that the flap can perfuse and any areas of hypoperfusion can be identified and trimmed.
- ◆ When using the gracilis flap, it is important to identify donor vessels in close proximity to the midface because the gracilis flap vascular pedicle is only 2 to 3 cm in length. The facial or superficial temporal vessels are located in good position for this flap.
- ◆ Once the vessels are prepared, the distal end of the facial nerve should be prepared for the neural anastomosis.
- ◆ Before harvesting the gracilis flap, it is essential to note the distance from the zygomatic periosteum to the corner of the orbicularis.
- ◆ Once the gracilis is exposed, we mark the muscle in extension with a marker and ruler so that after the harvest and the muscle contracts, we are able to stretch the muscle between the origin at the zygoma and the insertion at the orbicularis to achieve the optimal functional result. Remember, the muscle will contract following the harvest, and when sutured into position, the muscle will slowly extend to a length equivalent to its in-situ length prior to the harvest (**Fig. 4.31**).
- ◆ When the gracilis is in its final position, there should be tension on the commissure. The gracilis will extend and lengthen over the course of several days.
- ◆ Once the muscle has been sutured to the zygoma and the orbicularis, the vascular anastomosis can be performed followed by the obturator-facial nerve neural anastomosis.
- ◆ Once the gracilis reconstruction is complete, the posterior scalp flap can be transposed to complete the cutaneous portion of the reconstruction.



Fig. 4.31 The gracilis flap is then harvested with a skin paddle to reconstruct the intraoral defect.

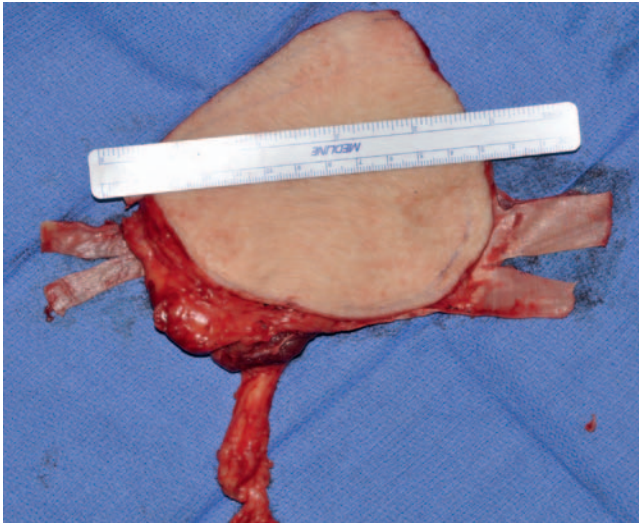


Fig. 4.32 The anterolateral thigh flap can be harvested with a vascularized tensor fascia lata static suspension.

Patient Selection and Perioperative Management

Dynamic facial reanimation requires that the facial nerve be available for reinnervation of the gracilis muscle flap and that the donor nerve be in good condition. This technique provides optimal results in younger patients, but it can yield good results in middle-aged patients, too. In cases where the posterior scalping flap is not available, the cervicofacial flap,

the submental flap, or the skin paddle associated with the gracilis flap can be used for cutaneous coverage. The skin paddle of the gracilis muscle can also be used for intraoral lining in cases where there is a through-and-through defect.

Postoperatively, the patient will not develop volitional motion for 8 to 12 months. Careful attention to wound care is vital to prevent an infection that might compromise the gracilis flap.

Option for Management: Anterolateral Thigh Flap with Tensor Fascia Lata Static Suspension

When dynamic reanimation is not a priority, the anterolateral thigh flap with tensor fascia lata grafts is an excellent choice for restoration of the defect involving the facial musculature. The drawback of this technique is the poor color match.

Surgical Technique and Considerations (Figs. 4.32, 4.33, and 4.34)

- ◆ Once the defect has been finalized and the margins are free of tumor, the flap can be harvested.
- ◆ The flap can be harvested with vascularized tensor fascia lata or with nonvascularized strips of tendon.
- ◆ The flap should be oriented such that the fascia can be directed in a vector that will appropriately raise the lip and midface.



Fig. 4.33 One-year postoperative anterior view demonstrates acceptable facial symmetry.



Fig. 4.34 One-year postoperative lateral view demonstrates poor facial color match but good facial suspension.

Patient Selection and Perioperative Management

This is a simple approach for management of the combined cutaneous–facial nerve defect where dynamic reconstruction is not a goal.

Option for Management: Latissimus Dorsi Flap with Neural Reinnervation

The latissimus dorsi flap can be used to reconstruct extensive cheek defects that involve the facial musculature as an alternative to a two-flap combination. The skin paddle can be used to resurface the cheek, and innervation of the latissimus muscle via the thoracodorsal nerve can be used to restore facial movement. Although this technique provides a single-flap option for extensive defects of the cheek, the drawbacks are related to the poor color and texture match of the latissimus dorsi skin paddle to the native cheek skin.

Surgical Technique and Considerations

- ◆ Once the ablative procedure is complete and the facial nerve stump has been dissected and isolated, the donor vessels should be prepared. Either the facial vessels or the superficial temporal vessels can be used for microvascular surgery.
- ◆ When harvesting the latissimus dorsi flap, we recommend using a nerve stimulator to identify and isolate the most active muscle bundles so that they can be incorporated into the flap.
- ◆ Once the most active muscle bundles have been identified, the skin paddle can be designed according to the defect and the muscle strip can be included in the flap design.
- ◆ When designing the skin paddle, it is important to consider the orientation of the muscle and its relation to the skin paddle so that the skin paddle fits into the defect and the muscle is oriented in the oblique direction.
- ◆ The muscle should be anchored proximally to the zygomatic periosteum with nonabsorbable sutures, and sutured to the orbicularis oris and the nasolabial fold with nonabsorbable sutures under tension.
- ◆ Once the muscle is in place, the tension of the muscle should draw the corner of the lip up to expose the second molar.

Patient Selection and Perioperative Management

In spite of the poor color match, the latissimus dorsi offers an excellent option for extensive cheek restoration. The motor function of the latissimus muscle can be adequate if time is spent during the harvest to isolate the most powerfully innervated muscle bundles. This approach is ideal for patients who cannot commit the time or have the dedication required for the staged posterior scalping flap technique and yet suffer from a cheek defect that is too large to be addressed with a submental island flap.

Postoperatively, facial movement will not be evident for 8 to 12 months. Reinnervation is best in younger patients and is less reliable in elderly patients or patients with a history of radiation therapy.

◆ **SOFT TISSUE DEFECTS OF THE CHEEK**

Tumors arising from the parotid gland may require extensive soft tissue resection, leaving a hollowed appearance to the cheek. Thus the reconstruction typically involves soft tissue volume replacement, and in some cases the reconstruction may require facial reanimation. Fat grafts or allogeneic fillers may be valuable for small-volume defects; however, large-volume defects typically require vascularized soft tissue reconstruction. The lateral arm, scapular fasciocutaneous flap, anterolateral thigh flap, or a variety of perforator flaps can be used to achieve an excellent result with minimal resorption.

Option for Management: Lateral Arm Flap

The lateral arm flap provides an excellent option for soft tissue augmentation of the parotid–cheek defect. As pointed out by Teknos et al,⁶ there are major advantages to the use of the lateral arm flap for complex parotidectomy defects: (1) well-compartmentalized fat, which resists ptosis; (2) ideal color match if skin coverage is necessary; (3) ready access to a long, multiple branching nerve during flap harvest, which can be used as a facial nerve graft; (4) the ability to harvest the flap with the patient in the supine position, allowing for a two-team surgical approach; and (5) minimal donor-site morbidity. Although soft tissue augmentation can be accomplished with a variety of donor sites, the lateral arm and anterolateral thigh offer excellent options.

Surgical Technique and Considerations

- ◆ The flap can be harvested with extra soft tissue and trimmed to the appropriate size during the inset.
- ◆ The distal aspect of the flap tends to be less bulky than the proximal aspect of the flap. This should be taken into account when orienting the soft tissue in the cheek defect.
- ◆ The peripheral aspects of the flap should be feathered to provide a smooth transition from the flap tissue to the native soft tissue of the cheek.
- ◆ The superficial temporal or facial vessels are often the best options for revascularization.

Patient Selection and Perioperative Management

The lateral arm flap provides an excellent donor site for cheek soft tissue augmentation. Although a variety of perforator flaps can also be used, the lateral arm donor site is reliable and relatively easy to harvest when compared with

other options. The flap swelling resolves over the course of 10 to 12 weeks. Soft tissue liposuction or sculpting may be necessary to achieve a suitable final result.

◆ THE THROUGH-AND-THROUGH DEFECT

Extensive lesions of the cheek often involve multiple contiguous structures requiring complete resection of the cheek, the underlying subcutaneous tissue, and occasionally the buccal mucosa. This results in a through-and-through defect of the cheek. Although some of these patients present in the primary setting, many present after multiple resections or following a course of chemotherapy and radiotherapy, and therefore the cheek skin may be compromised with regard to the ability to heal. In most cases, local and regional flaps are inadequate to provide tissue necessary to manage an extensive through-and-through defect. In general, free tissue transfer alone or in combination with a regional flap offers the best option for reconstruction. The radial forearm, the anterolateral thigh, and the latissimus dorsi are popular donor sites for through-and-through defects because all lend themselves to a bilobed skin paddle design. Choosing the appropriate donor site and orienting the flap represent the most significant challenges.

Option for Management: Radial Forearm Free Flap with Palmaris Tendon Reanimation

The radial forearm free flap provides enough tissue to create a double skin paddle flap to restore the intraoral lining and provide cutaneous coverage of the cheek. This palmaris longus tendon can be used for static facial suspension in those cases where suspension is indicated.

Surgical Technique and Considerations

- ◆ Once the resection has been completed and the margins have been assessed, the donor vessels can be dissected and prepared. The facial vessels are often in close proximity; however, to achieve the best pedicle geometry to avoid kinking, the transverse cervical vessels may be the optimal donor vessels for this flap.
- ◆ The flap design should include the palmaris longus tendon in a position that provides the axis of suspension that is desired to achieve facial suspension.
- ◆ The skin paddles should be designed to exactly fit the defect. Redundancy will compromise the final result.
- ◆ The intraoral flap should be sutured into place first. A perforation can then be made in the soft tissue to pass the tendon and secure it to the zygoma and orbicularis with a nonabsorbable 2.0 suture.
- ◆ The external skin paddle can then be sutured into the cutaneous defect, and the microvascular anastomosis can be performed.

Patient Selection and Perioperative Management

The reliability and versatility of the radial forearm donor site make it an attractive option for the through-and-through defect; however, there are several shortcomings with this technique. As discussed earlier, the color and texture match of the radial forearm skin is a poor match for the cheek. This donor site also provides a relatively thin piece of tissue, even when folded on itself to provide two skin paddles. As a result, long-term healing can lead to contraction and hollowing of the cheek. However, this technique offers a single-stage technique that can provide adequate coverage for the patient who cannot tolerate a more complex technique.

Postoperatively, we keep patients nil per os (NPO) for 7 days to allow intraoral healing unless the patient has been treated with radiation, in which case we maintain the patient NPO for 10 to 14 days. In some cases, the palmaris may require augmentation if the suspension is inadequate.

◆ THE THROUGH-AND-THROUGH COMPOSITE DEFECT

The through-and-through composite defect is a defect that involves the skin, the buccal mucosa, and the mandible (**Fig. 4.35**). It may result from an oral cavity tumor, a primary

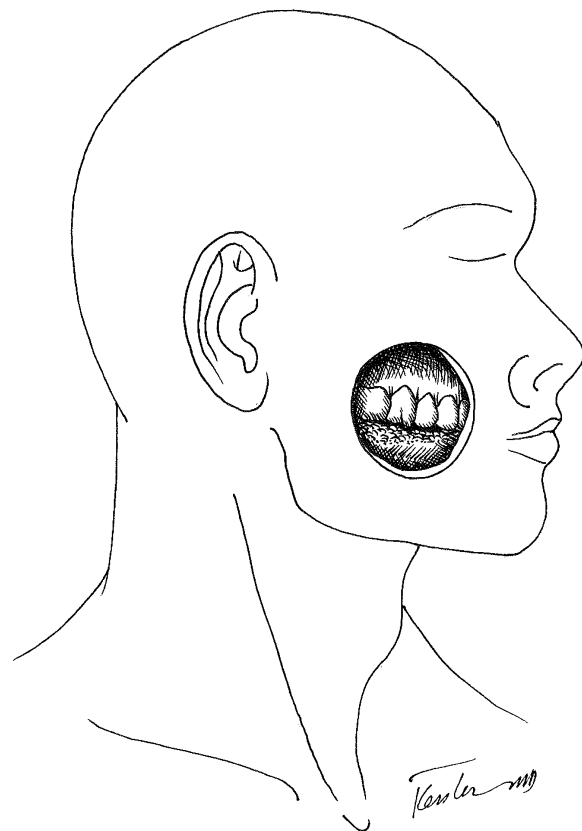


Fig. 4.35 Through-and-through cheek defect.

parotid tumor, or a skin cancer that has eroded through the buccal membrane into the buccal fat pad and through cheek skin. Most of these patients have had previous surgery or radiation, so the surrounding tissue is typically compromised. When approaching a through-and-through cheek defect, one needs to address both the anatomic subunit of the cheek to achieve an acceptable cosmetic reconstruction, and the functional separation of the outer skin defect with the oral cavity. The task becomes even more complex if facial reanimation is a goal. To achieve these goals, there are several reconstructive options, including a scapular free flap, a fibular free flap with two skin paddles, or a combination of flaps. The patient's expectations, the available donor sites, and the goals of the reconstruction with regard to aesthetics and function typically dictate the optimal donor site and reconstructive approach.

Option for Management: Scapular Free Flap

Uniquely, the scapular donor site provides the option to harvest two vascularized bone flaps, two separate skin paddles, and the latissimus dorsi muscle all based on a single vascular pedicle. These properties make it an excellent choice for complex defects of the cheek. Although the skin is a poor match for the cheek, the versatility of the tissue makes this donor site ideal for this type of defect.

Surgical Technique and Considerations

- ◆ Once the resection is complete and the donor vessels have been isolated, the reconstruction plate can be fixated to achieve mandible continuity and occlusion (**Fig. 4.36**).



Fig. 4.36 Clinical case. A through-and-through defect with composite mandibular defect.

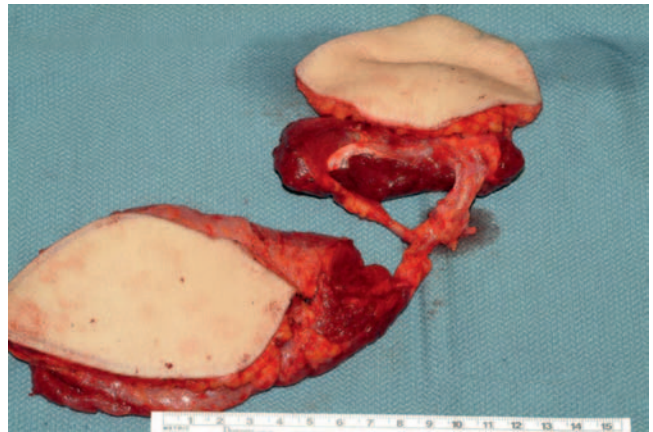


Fig. 4.37 The scapular donor site provides two vascularized skin paddles and a vascularized bone graft for complex reconstruction of the cheek.

- ◆ The design of the flap can be oriented so that the parascapular and scapular skin paddles are used separately to address the skin defect and the oral cavity defect, respectively, or the scapular skin paddle can be harvested to address the oral cavity defect and the latissimus dorsi can be harvested to manage the cutaneous defect (**Fig. 4.37**).
- ◆ We prefer to use the latissimus muscle with a skin graft to manage the cutaneous defect because the skin graft and muscle will atrophy and contract, thereby diminishing the cutaneous defect (**Fig. 4.38**).



Fig. 4.38 The skin paddle provides cutaneous coverage and intraoral lining.

- ◆ The bone graft should be fixated to the reconstruction plate followed by the intraoral reconstruction with the scapular skin paddle.
- ◆ The vessels should be drawn into the neck medial to the mandible to protect against compression of the pedicle.
- ◆ The latissimus dorsi muscle can then be used to reline the cutaneous defect. If facial reanimation is a goal, the muscle can be oriented appropriately and sutured to the zygomatic periosteum and the orbicularis oris.
- ◆ The vascular anastomosis is then performed and a skin graft is placed over the skin.
- ◆ Following the initial healing, secondary procedures can be performed to minimize the cutaneous scarring. We typically perform serial excisions of the skin graft to achieve the best aesthetic result.

Patient Selection and Perioperative Management

Patient selection is largely predicated on the complexity of the reconstruction. The scapular donor sites offer several options; however, other options, such as a fibula with two skin paddles, can be used. The scapular flap is reliable and versatile. The only drawback of this donor site is that the patient must be placed in the decubitus position during the harvest.

Postoperatively, the patient may benefit from serial excisions of the skin graft. If the latissimus dorsi skin paddle is used, this too may require debulking.

Option for Management: Fibular Free Flap with Posterior Scalping Flap

The fibular free flap can be used as a single flap with two skin paddles or in combination with a regional flap. Typically, the submental island flap is a difficult option because of the risk of submental metastasis and the potential to damage the submental vessels during the neck dissection. However, as long as the superficial temporal vessels are intact, the posterior scalping flap can provide an excellent source of skin coverage when the fibular skin paddle is used for the intraoral defect.

Surgical Technique and Considerations

- ◆ Once the resection is complete and the donor vessels have been isolated and prepared, we raise the posterior scalping flap so that it has time to perfuse during the fibular harvest.
- ◆ After raising the posterior scalping flap, the reconstruction plate is fixated and the fibula is harvested.
- ◆ The fibular bone is tailored to the bony defect and fixated and the skin paddle is used to reline the intraoral defect and partition the oral cavity from the outer cheek.

- ◆ The posterior scalping flap is then advanced to cover the cheek defect.

Patient Selection and Perioperative Management

This technique is an excellent option when a scapular flap is not available. It offers a better skin match and therefore a better aesthetic result. Postoperatively, the scalping flap will need to be staged and returned in 3 weeks.

◆ **SECONDARY RECONSTRUCTION OF THE SOFT TISSUE DEFECT**

Although uncommon, occasionally a patient who has undergone a prior radical neck dissection or parotidectomy requests a secondary reconstruction for cosmetic purposes. In the case of the parotid defect, the soft tissue deficiency may be mild to extensive, whereas the radical neck dissection deficiency as a result of the sternocleidomastoid muscle resection is usually more significant. Mild soft tissue defects of the parotid can be managed with fat injection, dermal grafts, dermal allografts, or a variety of injectables. In those patients who have been radiated, there are fewer options. Because nonvascularized tissue risks infection, vascularized tissue may be more appropriate, in particular for significant defects. Several vascularized tissue options are available for soft tissue augmentation of the parotid and the neck. The lateral arm, anterolateral thigh, and scapula offer soft tissue donor sites that are ideal for secondary soft tissue reconstruction. Because each donor site offers a hearty soft tissue flap, the ideal donor site is often predicated on the associated donor-site morbidity.

Option for Management: Lateral Arm

The lateral arm offers an excellent source of soft tissue that can be harvested with minimal donor-site morbidity and can be sculpted to the appropriate dimensions.

Surgical Technique and Considerations

- ◆ A careful assessment of the deformity should be made before the patient is induced with anesthesia to determine the areas of soft tissue deficiency (**Fig. 4.39**).
- ◆ The neck should be marked to demonstrate the areas that require augmentation before beginning surgery to prevent the distortion that occurs with soft tissue swelling after the incision (**Fig. 4.40**).
- ◆ The donor vessel can then be identified and isolated. In most cases, the transverse cervical vessels are preserved after a radical neck dissection.
- ◆ Once the vessels have been isolated, the lateral arm flap can be harvested. The flap can be harvested with a skin paddle for a monitor or without a monitor paddle (**Fig. 4.41**).



Fig. 4.39 Clinical case. The cosmetic deformity associated with the radical neck dissection defect.

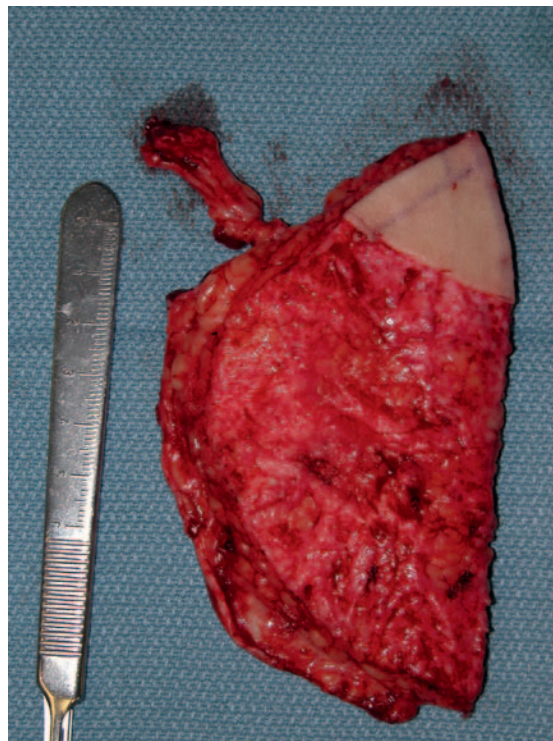


Fig. 4.41 The lateral arm free flap with monitoring paddle.



Fig. 4.40 Marking demonstrating the area of soft tissue deficiency.

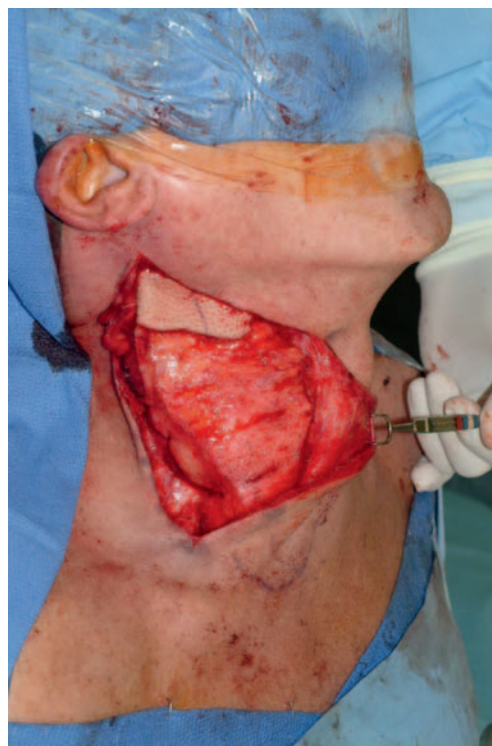


Fig. 4.42 The lateral arm flap in situ. The transverse cervical vessels are used for revascularization.

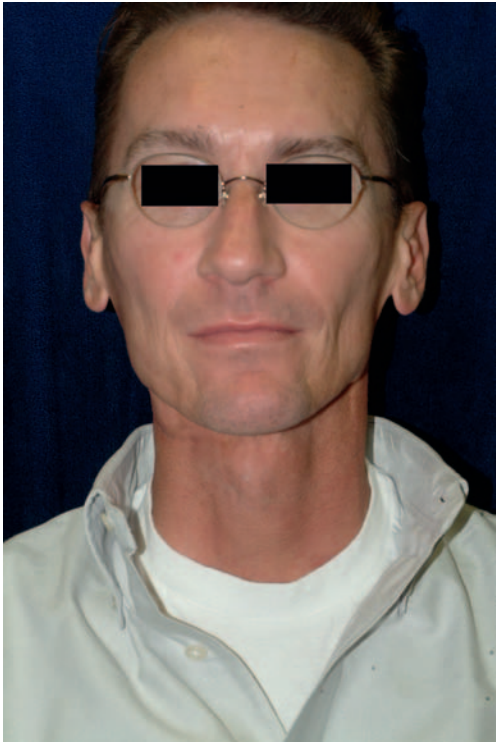


Fig. 4.43 The one-year postoperative result demonstrates a durable cosmetic restoration with symmetry of the neck.

- ◆ Once the flap is placed into the neck, the soft tissue should be sculpted to simulate the sternocleidomastoid muscle (**Fig. 4.42**). We typically overcorrect with soft tissue by about 10%.
- ◆ The edges of the flap should be tapered to achieve a natural, seamless transition into the native neck tissue.
- ◆ The vascular anastomosis is done as the last step of the procedure, and touch-up trimming of the tissue is performed after revascularization (**Fig. 4.43**).

Patient Selection and Perioperative Management

Careful patient selection is essential. We recommend a disease-free interval of 2 years before considering cosmetic augmentation in those patients with a history of malignant disease, and a 1-year interval in patients with a history of benign disease. Perioperatively, we allow a minimum of 8 weeks before secondary augmentation. Secondary augmentation can be achieved with standard liposuction or open debridement.

◆ CONCLUSION

Reconstruction of the cheek represents a unique challenge because the cosmetic and functional considerations are so crucial to the final outcome. Achieving a skin color and texture match and the considerations related to facial reanimation are a difficult combination. This chapter proposed a variety of options, ranging from the scalping flap to the submental island flap. The addition of facial reanimation increases the complexity of the reconstructive challenge. In the final analysis, the approach to reconstruction requires an in-depth discussion with the patient related to the patient's goals. This often provides important information that can be used to guide the approach to reconstruction.

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5

Pharynx, Cervical Esophagus, and Hypopharynx Reconstruction

Matthew Old and Theodoros N. Teknos

The upper aerodigestive tract is a complex organ responsible for deglutition, respiration, and communication. Cancers and disease of this organ often impact these functions and are detrimental to a patient's quality of life. The primary goal of the head and neck reconstructive surgeon is to obtain a safe and stable wound, but it is imperative during reconstruction that the surgeon account for these issues to have a successful functional outcome. In the era of increasing primary chemoradiation for many tumors, wound complications for salvage surgery and reconstruction have become routine. Understanding the functional principles of defects and the potential reconstructive options is necessary to obtain a safe wound, reduce complications, and improve the quality of life.

Wound breakdown and infections often result in pharyngocutaneous fistula and potential great vessel rupture. The incidence of pharyngocutaneous fistula is up to 75% for salvage surgery within 3 months of completing chemoradiation.¹ Fistulas for patients who have been treated with radiation occur in 25 to 30%.² The incidence of carotid blowout syndrome is between 3 and 4% of all head and neck cases, with increasing occurrences in patients who have had preoperative radiotherapy.³

To reduce the incidence of morbidity related to these wounds complications, reconstructive surgeons use vascularized tissue via regional or free flaps. Vascularized flaps have the advantage of providing supplemental tissue to restore some function to the organ. In the setting of postradiation wounds, both regional and free flaps bring tissue from outside the radiation fields. This has been shown to significantly reduce the incidence of major wound complications but not the incidence of fistula.⁴

The Montgomery salivary bypass tube is a plastic conduit inserted at the time of reconstruction or after fistula development to reduce and prevent salivary flow over or through the suture line. It has been shown to significantly reduce the incidence of strictures, major wound complications,

and length of stay in the hospital, but not the incidence of fistula.⁵

Optimal nutrition and metabolism are critical factors to account for to obtain a successful outcome. Nutrition is often difficult to optimize in the head and neck cancer patient, but it is a factor we often overlook. Hypoalbuminemia, anemia, and weight loss 6 months prior to surgery have been found to be independent predictors of wound complication in laryngectomy patients.⁶ Additionally, proper thyroid function or supplementation is imperative. Hypothyroidism is well known to increase wound complications and is common in the head and neck cancer patient, with an incidence up to 48%.⁷ Supplementation of exogenous thyroid hormone hastens wound healing; thus, preoperative assessment of thyroid function is necessary in the postradiation patient.⁸

◆ RELEVANT FUNCTIONAL ANATOMY

The pharynx and cervical esophagus are fundamentally essential structures to swallowing, speaking, and respiration. The pharynx extends from the cranial base to the level of the cricoid cartilage and is subdivided into the nasopharynx, oropharynx, and hypopharynx. The hypopharynx is contiguous with cervical esophagus. The pharynx is encompassed by horizontal muscle fibers of the superior, middle, and inferior constrictors, which are responsible for the contraction of the tubular organ and propulsion of the food bolus into the upper esophagus. Elevation of the pharynx and larynx via the vertically oriented stylopharyngeus, palatopharyngeus, and salpingopharyngeus muscles leads to improved movement of the bolus into the esophagus and protection of the larynx. The inferior constrictor and cricopharyngeus muscles act as a sphincter to prevent the entrance of air into the esophagus. This is a complex coordinated reflex that is often impaired in head and neck patients.

The superior function of the pharynx is aided by the movement of the soft palate. The soft palate acts to prevent air and food escaping through the nose via the nasopharynx by forming a seal with the posterior and lateral pharyngeal walls. Conversely, during respiration, air is allowed to pass through the nose and nasopharynx via relaxation. Dysfunction of the soft palate can lead to significant impairment of speech and swallowing via palatopharyngeal (velopharyngeal) insufficiency, degrading the patient's quality of life. The nasopharyngeal port formed by the soft palate and the lateral and posterior pharyngeal walls is approximately at the level of the occlusal plane of the teeth. This is an important landmark for reconstructing the soft palate defect.

◆ FUNCTIONAL REHABILITATION

Reconstructive goals of pharyngeal and esophageal defects center on restoration of an oral diet, respiration, and communication. Integral to these goals is the basic concept of replacing missing tissue with similar tissue. Local, regional, or free flaps are better suited for reconstruction if they emulate the structure to be replaced. Most of the pharynx and esophagus is thin, mobile, and pliable, and thus reconstructive tissue should be similarly modeled. Thick bulky local, regional, or free tissue flaps should be avoided if possible. Healing by secondary intention or direct closure often leads to superb results if chosen in the right defects. Skin grafts can be appropriate if the proper vascular bed is available. Local flaps are advantageous, as similar tissue is brought into the field. The most versatile tissue is from microvascular free flaps. Proper planning and tissue choice are absolutely necessary to obtain a safe and functional outcome.

◆ CLASSIFICATION OF DEFECTS

We have divided defects of the pharynx and esophagus into categories that facilitate a systematic approach to reconstruction. Each category has unique characteristics to consider during reconstruction. The lateral pharyngeal defect involves the pharynx superior to the hypopharynx and posterior to the soft palate. The posterior pharyngeal wall is at the same level but lies between the two lateral pharyngeal walls. It is the least mobile of all the structures. Contrasting with the posterior pharyngeal wall defect is the soft palate, which is the most mobile and sensitive structure. Velopharyngeal incompetence is a devastating consequence of scarring and inadequate reconstruction of the soft palate, affecting swallowing and communication. The cervical esophagus extends from just inferior to the postcricoid region to the thoracic inlet. Defects are subdivided into partial and circumferential and are treated in vastly different ways. Laryngopharyngeal and hypopharyngeal defects differ in terms of the presence or absence of the larynx. The combination defect, which includes a large portion of the trachea, laryngopharynx, and potentially the esophagus, is a challenging reconstructive problem that requires involvement of our thoracic colleagues.

◆ THE LATERAL PHARYNGEAL DEFECT

The lateral pharyngeal defect often involves the mucosa and underlying superior constrictor. Restoration of movement is the ultimate goal but can only be obtained if the muscle is not involved or if free edges can be realigned via primary closure. Healing by secondary intention is appropriate if the defect is small and does not include a through-and-through defect into the neck, as in transoral laser microsurgery. Care should be taken in this treatment decision, as secondary healing often leads to contraction and scarring. If excessive scarring occurs near or at the soft palate or glossotonsillar sulcus, velopharyngeal insufficiency or tongue tethering, respectively, can result. In these cases, alternate reconstruction should be chosen. If scarring encroaches on the soft palate, the reconstructive surgeon should have a low threshold for performing some level of palate reconstruction, as outlined in this chapter. If the defect is large and involves the glossotonsillar sulcus, consider free tissue transfer instead of primary closure or healing by secondary intention.

Option for Management: Primary Closure

If the defect is small (<2–3 cm) and does not involve the soft palate or glossotonsillar sulcus, primary closure can be adequate for a successful reconstruction. Careful layered closure including mucosa and muscle should be performed with Vicryl or similar suture. If the defect communicates with a neck dissection or involves exposed great vessels, it is imperative to ensure a watertight seal and reinforce it with tissue. Rotating vascularized tissue such as digastric or stylohyoid muscle is advantageous but sometimes not possible. A dermal graft works well to reinforce the suture line and provide one more layer of protection over the vessels. If the defect is greater than 3 cm, primary closure can alter the anatomy too much and lead to swallowing impairment and aspiration. A local, regional, or free tissue transfer should be considered in the case.

Option for Management: Regional Flaps

Regional flaps such as the pectoralis myocutaneous (PM), lateral island trapezius, deltopectoral flap, submental island flap, and latissimus myocutaneous flaps are options to be considered in lateral pharyngeal wall defects (**Fig. 5.1**, **Fig. 5.2**, **Fig. 5.3**, and **Fig. 5.4**). The limitation of these flaps is the bulky nature of the myocutaneous paddles and the reduced pliability, which is essential for reconstruction of this area. However, in vessel-depleted necks, these flaps can serve as good alternatives to free flaps. If great vessel exposure is a problem, these regional flaps can provide excellent coverage of the carotid artery and jugular vein.

Surgical Technique and Considerations

- ◆ Place a feeding tube prior to reconstruction if a gastrostomy tube is not already present.
- ◆ The cutaneous paddle of the regional flap should be designed as distal as possible but still over the muscle.



Fig. 5.1 The regional flap options for pharyngeal reconstruction include the deltopectoral flap, the island deltopectoral flap, the pectoralis flap, and the submental island flap. Demonstrated are the options for incisions (*dotted lines*) to preserve the deltopectoral flap while harvesting the pectoralis myocutaneous flap. The blood supply to the deltopectoral flap and island deltopectoral flap are the three intercostals branches of the internal mammary vessels (*arrows*).

Do not raise any portion of the skin paddle that is not over the muscle, as the blood supply is less reliable.

- ◆ For the PM flap, make sure the tunnel over the clavicle and into the pharynx is wide enough to accommodate the pedicle (**Fig. 5.2**).
- ◆ The latissimus flap should be passed through a generous tunnel between the pectoralis major and pectoralis minor into the neck. Once it has been passed, check to make sure the vascular pedicle has a gentle curvature and is not kinked.



Fig. 5.2 The pectoralis myocutaneous flap can be effectively used to patch the lateral pharyngeal defect. The muscle of the pectoralis can be used to protect the great vessels. This is particularly useful in patients who have been previously treated with radiotherapy.

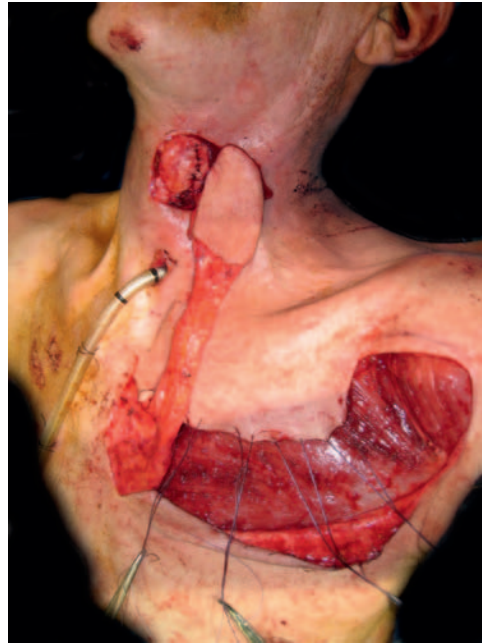


Fig. 5.3 The island deltopectoral flap provides a thin pliable source of tissue for small and moderate-sized defects of the pharynx. The flap is rotated into the defect.

- ◆ If the patient had a previous neck dissection or if there is variable vascular anatomy, the trapezius flap may not be available. The transverse cervical vessels need to be intact for this regional flap to work. The lateral island trapezius flap has a significant abort rate of up to 30% in one series⁹.



Fig. 5.4 Three weeks after deltopectoral flap reconstruction. The skin flap has been folded to provide internal pharyngeal lining and external skin lining.

Patient Selection and Perioperative Management

Latissimus flap patients should have their arm in a sling immediately after surgery for at least 5 days to prevent compression of the pedicle. We allow a minimum of 5 to 7 days prior to initiation of oral feeding under the care and guidance of a speech pathologist. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube.

Option for Management: Radial Forearm Fasciocutaneous Free Flap (RFFF)

The RFFF is a versatile reconstructive tool. It is thin and pliable and can be used to reconstruct multiple compartments of the pharynx and soft palate. Unless the patient is obese, this flap lacks a significant amount of fat and bulk. Bulk is important with significant defects of the base of tongue. If >50% of the base of tongue is missing along with the pharyngeal defect, we prefer to use a flap with more bulk. The lateral arm typically has more fat than the forearm, and we tend to use this in cases where a good portion of the base of tongue is missing. If the lateral arm is not available, the brachial fat pad or surrounding fat can be harvested with the RFFF and used to provide bulk to the base of tongue segment.

Surgical Technique and Considerations (Fig. 5.5 and Fig. 5.6)

- ◆ The forearm can be harvested from either arm if the Allen's test is appropriate bilaterally. We tend to choose the nondominant arm.
- ◆ Once the defect is defined, a template of the defect should be made. This assists with aligning the vessels appropriately, ensuring good geometry, and capturing

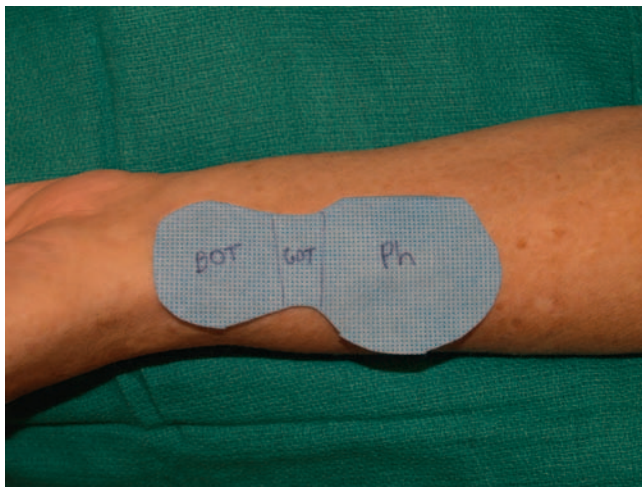


Fig. 5.5 Template positioned on forearm to ascertain proper geometry. Template for lateral pharynx reconstruction. BOT, base of tongue; GOT, glossotonsillar sulcus; PH, pharynx including tonsillar fossa and pillars.

the cephalic vein. The template is transposed to the forearm and the flap planned and harvested in standard fashion. This is particularly useful if different compartments need to be reconstructed.

- ◆ If the base of tongue segment needs more bulk, fat can be harvested adjacent to the cutaneous paddle and folded underneath that portion of the flap as we did in this case.
- ◆ Following the harvest, the flap is transferred into the defect and sutured with interrupted 3-0 Vicryl to form a watertight seal.

Option for Management: Lateral Arm Free Flap

The lateral arm free flap is particularly useful in reconstructing the pharynx if there is a significant base-of-tongue defect (>50%). It is a favorable donor site with little morbidity associated with it. Distal extension of the flap provides thinner tissue than the proximal flap. The pedicle length is more limited than the forearm flap but can be extended by designing the flap more distally and tracing the pedicle up the spiral groove. The profunda brachii artery can be used to lengthen the pedicle as the anterior radial collateral artery is typically ligated. The profunda has a caliber of 1.75 to 2.7 mm high in the spiral groove of the radius.¹⁰

Surgical Technique and Considerations (Fig. 5.7)

- ◆ Once the defect is defined, appropriate recipient vessels should be obtained because the limitation of this flap is often pedicle length. We tend to favor the occipital artery or facial artery for this flap. The occipital often is a similar match in caliber. If length will allow, the superior thyroid artery may serve as a good donor vessel.

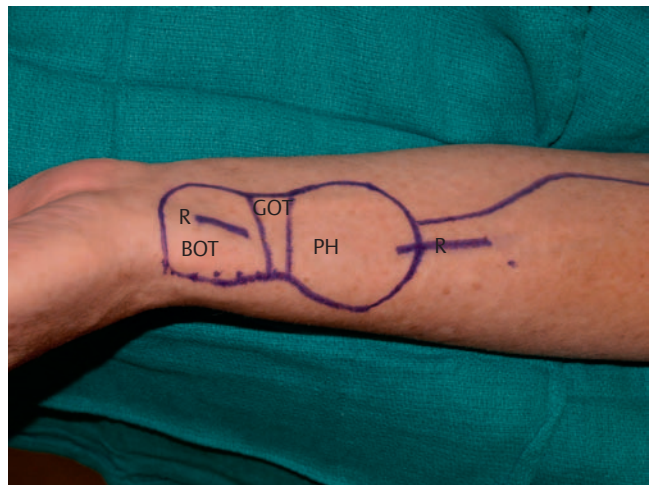


Fig. 5.6 Template outlined and ready for harvest with good pedicle geometry. BOT, base of tongue; GOT, glossotonsillar sulcus; PH, pharynx including tonsillar fossa and pillars; R, radial artery.

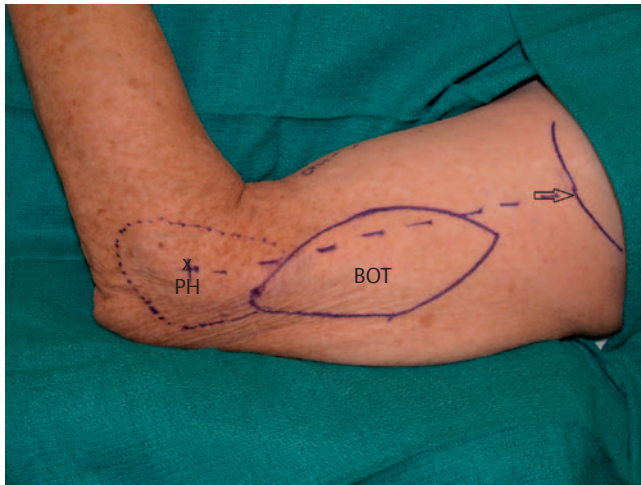


Fig. 5.7 Lateral arm design with extension (*dashed line*) if thinner tissue needed for reconstruction. +, lateral epicondyle; arrow, deltoid insertion; BOT, base of tongue; PH, pharynx including tonsillar fossa and pillars.

- ◆ Take only as much skin (approximately one third of the arm) as can close primarily. It is generally 6 to 8 cm wide. A pinch test of the skin once the patient is asleep is a good measure of the quantity that can be harvested. If it can't be closed primarily, a skin graft is necessary, but we tend to avoid this.
- ◆ If the patient has a significant amount of adipose tissue, the flap can be designed distally to capture thinner skin and subcutaneous tissue. Some groups have harvested tissue as far as 10 cm distal to the lateral epicondyle.¹¹
- ◆ For defect of the lateral pharynx with significant base of tongue involvement, we use the proximal portion of the flap for the base-of-tongue defect and the thinner distal portion for the glossotonsillar sulcus and lateral pharynx.

Option for Composite Mandibular and Pharynx Defects: Fibular Free Flap

Composite defects that include the mandible, pharynx, soft palate, floor of mouth, and/or part of the tongue are best reconstructed with an osteocutaneous fibular free flap. Large, thin, pliable cutaneous paddles can be obtained to reconstruct these defects. There is a large bone stock and vascular pedicle. It is difficult for the flap to provide sufficient bulk for glossectomy defects, and it does not provide good-quality combined internal and external lining. Both of these limitations are solved by using a scapular osteocutaneous free flap.

Surgical Technique and Considerations

- ◆ Obtain a computed tomography (CT) angiogram or a magnetic resonance angiogram (MRA) to assess the vasculature for a three-vessel run-off to the foot. This aids in the selection of the leg to use or in deciding if this flap should be abandoned altogether. This flap

should be aborted if a congenital anomaly exists or if peripheral vascular disease has compromised the anterior or posterior tibial arteries.

- ◆ Once the defect is defined, perforators are mapped out on the leg and the cutaneous paddle designed in standard fashion.
- ◆ We typically prefer the contralateral leg. The pedicle comes off the back. If the ipsilateral leg is used, the pedicle exits from the front.

Patient Selection and Perioperative Management

Following reconstruction of the lateral pharynx, we place a nasogastric feeding tube if a gastrostomy tube is not already present. We allow a minimum of 5 to 7 days prior to initiation of oral feeding under the care and guidance of speech pathology. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube. If there is concern about a leak, we obtain a swallow study to document the location and quality of the leak and resume nil per os (NPO) status.

◆ THE POSTERIOR PHARYNGEAL DEFECT

The isolated posterior pharyngeal wall defect is uncommon but when present can be a difficult reconstructive challenge. Access to this area for reconstruction is typically via the neck, but occasionally the approach is transoral. An important aspect of the posterior pharyngeal wall defect is whether or not the spine is involved. Frequently the prevertebral fascia is intact, but in spine cases or when bone has been resected, care should be taken to ensure separating the pharyngeal tract from the spine. This is imperative, as the patient is at risk for cerebrospinal fluid (CSF) leaks, osteomyelitis, and epidural infections, which can be devastating. Small defects that include mucosa and muscle but have no connection to the neck often heal by secondary intention. Good oropharyngeal hygiene should be maintained throughout this process.

Option for Management: Primary Closure

If the prevertebral fascia is intact and the defect is limited to 2 to 3 cm, the mucosa and muscle can be dissected and mobilized. If the edges are able to be approximated with little tension, primary closure is suitable. The muscle should be closed in interrupted fashion with Vicryl or similar suture. The mucosa should then be closed as well with Vicryl sutures. We prefer 3.0 Vicryl for our closures.

Option for Management: Skin Graft or Healing by Secondary Intention

If the defect is too large for the edges to be mobilized and closed primarily, healing by secondary intention or skin graft is a powerful tool. As long as the bed to host the graft or

healing by secondary intention is vascular and can support the process, this is an appropriate choice.

Surgical Technique and Considerations

- ◆ The remnant edges should be tacked down to the prevertebral fascia to create a watertight seal and barrier from the neck.
- ◆ We tend to prefer healing by secondary intention, but a split-thickness graft can be harvested and tacked into place. The graft should be quilted and fixed into place in multiple locations. A bolster is not feasible.
- ◆ The preferred option is to allow the area to heal by secondary intention after the remnant edges are fixed down to the fascia with interrupted Vicryl sutures to form a watertight seal.

Option for Spine Plus Pharynx Reconstruction: Fibular Free Flap

Circumstances arise, particularly in spine surgery, when a free flap is needed to reconstruct the vertebral column. If spinal hardware becomes exposed to the pharyngeal compartment, there is not much choice but to remove the hardware. Unfortunately, this may lead to spinal instability, and thus the spinal surgeon often plans a reconstruction at the same time. The osteocutaneous fibular free flap provides vascularized bone that can support reconstructive plating, as well as vascularized skin that can be used to separate the pharynx from the vertebral column if the mucosa and fascia are in poor condition. It is rare in hardware exposure and osteomyelitis cases that the mucosa is in good condition so the fibular skin paddle can be handy to seal the pharynx from the spinal defect. Communication with the spinal surgeon is key to assessing exactly what the needs are for each patient.

Surgical Technique and Considerations

- ◆ The patient should have a tracheostomy in place, as flap swelling postoperatively is unpredictable.
- ◆ Obtain a CT angiogram or an MRA to assess the vasculature for three-vessel run-off to the foot. This aids in the selection of the safe leg to use or in deciding if this flap should be abandoned. This flap should be aborted if a congenital anomaly exists or if peripheral vascular disease has compromised the anterior tibial or posterior tibial arteries.
- ◆ Assess the pharyngeal defect and map out an appropriate skin paddle with the Doppler.
- ◆ Perform a neck exploration for vessels prior to harvesting the flap. We prefer the facial, superior thyroid, or transverse cervical artery for this flap.
- ◆ After harvest, discuss and measure the required bone for reconstruction. Perform a subperiosteal dissection to lengthen the pedicle and acquire the appropriate bone length. Trim as necessary.

- ◆ With the assistance of the spinal surgeon, place the bone in the needed location and affix it. Perform the microvascular anastomosis prior to securing the skin paddle. Ensure that there are no geometry issues.
- ◆ If the spine reconstruction is high (C1-3), we prefer to have the pedicle exit inferiorly with the distal part of the bone and skin paddle superior. This helps prevent kinking of the pedicle. If the reconstruction is lower, orient it either way and assess the best geometry to prevent compromise of the vasculature.

Option for Pharynx Only: Radial Forearm Free Flap

The radial forearm fasciocutaneous free flap is a versatile reconstructive tool for large posterior pharyngeal wall defects. It is thin and pliable and can be used to reconstruct multiple compartments if needed. It can also reach higher than most pedicled flaps. We prefer to use this flap in superior pharyngeal defects due to the long pedicle and versatile design. The regional flaps are bulkier and difficult to extend this high.

Surgical Technique and Considerations

- ◆ The forearm can be harvested from either arm if the Allen's test is appropriate bilaterally. We tend to choose the nondominant arm.
- ◆ Once the defect is defined, a template of the defect should be made. This assists with aligning the vessels appropriately, ensuring good geometry, and capturing the cephalic vein. The template is transposed to the forearm, and the flap is planned and harvested in standard fashion. This is particularly useful if different compartments need to be reconstructed.
- ◆ Following the harvest, the flap is transferred into the defect and sutured with interrupted 3.0 Vicryl suture to form a watertight seal.

Patient Selection and Perioperative Management

Following reconstruction of the pharynx, we place a nasogastric feeding tube if a gastrostomy tube is not already present. We allow a minimum of 5 to 7 days prior to initiation of oral feeding under the care and guidance of a speech pathologist. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube.

◆ THE SOFT PALATE DEFECT

The soft palate defect is one of the most challenging defects to reconstruct. The mobility and function of the soft palate is complex, and alteration of this function can lead to velopharyngeal insufficiency (VPI) and dysphagia. Traditionally, a palatal prosthesis was used for many defects, but with the expansion of reconstructive options, these are reserved for

small defects (central and less than one fourth) of the palate). A palatal prosthesis is also an option in patients who are too ill for reconstruction or refuse the surgery. Hemipalate defects are poor candidates for palatal obturation.

The key aspect of soft palate reconstruction is to seal the nasopharynx from the reflux of air and food during speech and deglutition, respectively. Additionally, the reconstruction should allow airflow in both directions that is balanced so that speech is neither hyper- or hyponasal. Lateral defects of up to one third of the palate can be closed primarily or with a palatal island flap. Defects greater than one third of the palate are best served with a radial forearm free flap.

Option for Management: Obturation

We reserve obturation for patients who fail reconstruction, are too ill to undergo lengthy surgery, or refuse the reconstructive effort. A good prosthodontist is critical to the successful outcome of properly chosen soft palate defects. Palatal obturators are best suited when the defects are small (less than one fourth of the soft palate), central, and do not involve the free edge. This allows for continued function of the lateral pharyngeal walls and remnant soft palate. The patient should have adequate dentition or implants to support the prosthesis and forces that will occur. Some individuals do not tolerate these devices due to an overactive gag reflex.

Option for Management: Palatal Remnant Adhesion

One of the easiest and most overlooked techniques to prevent VPI is a palatal adhesion. This narrows the port and prevents incompetence. Lateral defects of the soft palate often include a portion of the pharynx. Allowing the defects to heal by secondary intention entails a high risk of palatal remnant retraction and subsequent VPI, a hypernasal voice, and reflux of oropharyngeal contents into the nose. Performing an adhesion between the nasal mucosal side of the remnant soft palate and the pharyngeal remnant will close and narrow the nasopharyngeal port. Healing can then occur by secondary intention, skin grafting, or flap reconstruction. This simple technique also creates a port with function rather than a static flap-reconstructed port. Use caution when doing this if greater than 50% of the soft palate and pharynx are gone. If significant narrowing occurs, oropharyngeal or nasopharyngeal stenosis can occur, resulting in hyponasal speech and nasal obstruction.

Surgical Technique and Considerations

- ◆ If a feeding tube is going to be placed, it is important to do so prior to the adhesion. Any nasopharyngeal instrumentation after the reconstruction has been performed risks tearing open the repair.
- ◆ Undermine the remnant pharynx beneath the constrictor muscle and roll it medially enough so that the adhesion will be relatively tension free.

- ◆ Use 3.0 Vicryl sutures to form a seal between the pharynx remnant and the nasal side of the soft palate remnant.
- ◆ The uvula can be used as part of the repair line if needed.
- ◆ If less than 30% of the soft palate is gone, some may choose to let this heal by secondary intention. A patch with a radial forearm can be placed as well.

Option for Management: Local Flaps

The palatal island flap is a versatile tool for reconstruction of various oral cavity and some limited oropharyngeal defects. It is based on the greater palatine artery, and the flap can be rotated 180 degrees. It is good for retromolar trigone defects and lateral soft palate defects that do not involve the free edge of the soft palate. We prefer to use the contralateral artery for the pedicle. The hamulus may be removed and the foramen may need opening to allow for better rotation. Caution should be used with this flap to ensure that it does not pull the soft palate edge forward too much. If there is concern, a small adhesion between the soft palate edge and posterior pharyngeal wall is advised; it is easy to do and involves demucosalizing a small segment of the free edge and sewing it to a demucosalized segment of the posterior pharyngeal wall.

Surgical Technique and Considerations

- ◆ Nasotracheal intubation in these patients (or tracheostomy, if warranted) allows full access to the oral cavity or oropharynx.
- ◆ If the patient does not have a mandibulotomy, a Dingman mouth retractor is useful in these scenarios.
- ◆ Leave 5 mm of gingiva and expect approximately 30 to 40% shrinkage after the incisions are made.
- ◆ Consider an adhesion if necessary.
- ◆ If a feeding tube is going to be placed, it is important to do this prior to the adhesion. Any nasopharyngeal instrumentation after the reconstruction has been performed risks tearing open the repair.
- ◆ There are many options for the open hard palate donor site. We prefer aggressive oral care and rinses to aid in the remucosalization of the site.
- ◆ We place our patients on a liquid diet and advance them as tolerated to soft foods depending on the extent of pharyngeal involvement.

Option for Management: Radial Forearm Free Flap

Secondary to local flaps is the radial forearm free flap. It is thin and pliable and better suited at reconstructing large (greater than one third of the palate) through-and-through palatal defects. If the defect contains multiple subunits of the oropharynx (tongue base, pharynx, and palate), the radial forearm is far superior to other local, regional, or free tissue flaps due to its pliability, long pedicle length, and robust

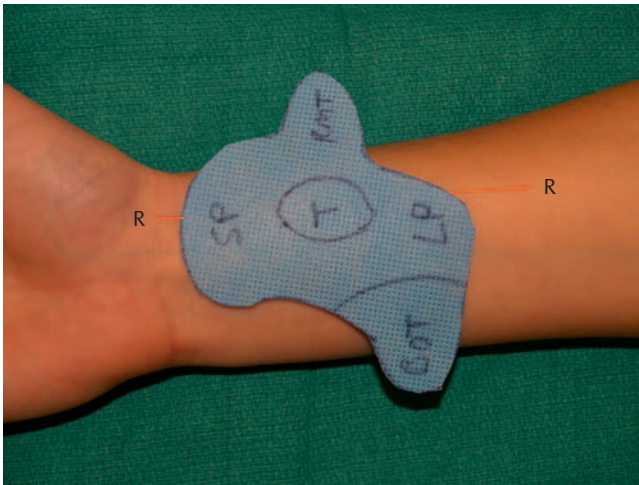


Fig. 5.8 Complex template of soft tonsil cancer defect of soft palate, pharynx, retromolar trigone, and base of tongue. BOT, base of tongue; LP, lateral pharynx; R and red line, radial artery; RMT, retromolar trigone; SP, soft palate; T, tonsil. A complex oropharynx defect template is transposed to the forearm to assist with pedicle geometry and appropriate geometry.

blood supply. It is advantageous to use templates in these defects, as the three-dimensional nature of the reconstructions can be confusing (**Figs. 5.8 and 5.9**).

Surgical Technique and Considerations

- ◆ Tracheostomy is warranted in these reconstructions. The swelling of the free tissue is unpredictable

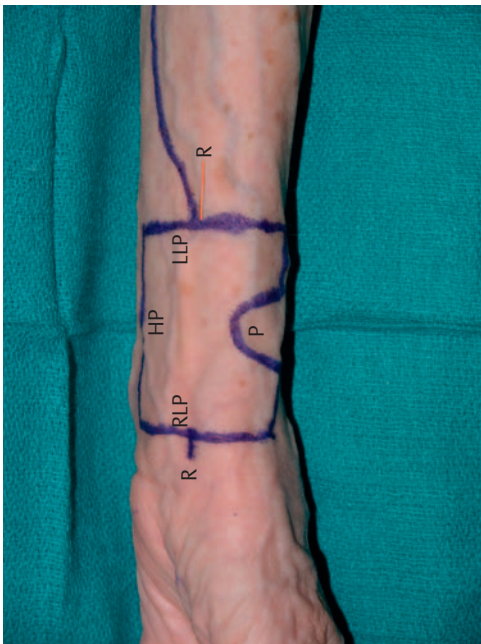


Fig. 5.9 Total soft palate reconstruction. HP, superior aspect of flap sutured to hard palate; LLP, left lateral pharynx; P, new nasopharyngeal port at occlusal plane; R, radial artery; RLP, right lateral pharynx.

postoperatively. It also provides the surgeon with good access in this region.

- ◆ If the patient does not have a mandibulotomy, a Dingman mouth retractor is useful in these scenarios.
- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a gastrostomy tube is not in place.
- ◆ Once the margins are clear, access any remaining soft palate. If there is a remnant (approximately one third), adhere the nasal side of the palate to the free margin of the pharynx defect to create a small port as described above. The forearm flap will then lie into the defect and need no separation from the nose.
- ◆ If it is a full palate defect, a template is advantageous to create a suitable reconstruction and accurate pedicle geometry. **Figure 5.9** shows the design. The authors prefer to create a nasopharyngeal port in the center. The critical measurement is to place the new nasopharyngeal port at the same level as the occlusal plane.
- ◆ The nasal side of the flap will remucosalize over a 4- to 6-week period.
- ◆ Nasal rinses and speech therapy are important in the postoperative setting.
- ◆ A second option is to fold the flap in half, and adhere a de-epithelialized central segment to the posterior pharyngeal wall. The nasal side will be lined with skin, and thus remucosalization will not be needed for healing.

Patient Selection and Perioperative Management

Following minor reconstructions of the soft palate (local flaps or primary closure), we allow patients to resume a liquid to soft diet immediately, coupled with good oral hygiene and care, but a regular diet is avoided for 1 week. With major reconstructions of the soft palate, we place a nasogastric feeding tube if a gastrostomy tube is not already present. We allow a minimum of 5 to 7 days prior to initiation of oral feeding under the care and guidance of a speech pathologist. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube.

◆ THE PATCH REPAIR FOR CERVICAL ESOPHAGUS

Cervical esophageal repair may be necessary for a variety of reasons. Some are postablative procedures, but often the isolated repair is for a persistent esophageal stricture. These strictures are often secondary to prior radiation and repeated failed dilation attempts. In these cases, patch repair of the esophagus can be undertaken with a variety of techniques. The main principle for strictures or defects is the interposition of healthy tissue to increase or restore the lumen and “patch” it. Strictures should be opened longitudinally, and the lumen increased by interposing the healthy tissue above,

at, and below the stricture. Limiting the reconstruction to the stricture itself may lead to circumferential scarring.

A key factor for all repairs or reconstructions is to use thin, pliable tissue. This varies from patient to patient. A PM flap can be quite thick and laborious to put into a defect if the patient has a large body habitus. We tend to prefer the radial forearm free flap as it is flexible, thin, and versatile even if patients are overweight.

Option for Management: Regional Flaps

There are many regional flaps for the patch repair of an esophageal defect, including the pectoralis myocutaneous, platysma, deltopectoral island flap, and the lateral island trapezius flap. These numerous options frequently are not available or suitable for the repair. Careful patient selection and design are necessary in each of these flaps. In patients with a vessel-depleted neck, these regional flaps are a decent alternative.

Surgical Technique and Considerations

- ◆ Tracheostomy is typically not needed unless the patch defect extends close to the hypopharynx.
- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a gastrostomy tube is not in place.
- ◆ Enter the stricture vertically or assess the defect and decide the necessary tissue to adequately augment the lumen. We prefer a 3-cm-diameter lumen in ideal scenarios, which equates to approximately 9 cm in circumference. Subtracting the size of the existing tissue from 9 cm will give the tissue measurement needed from the flap. It is not always possible to obtain this diameter with regional flaps.
- ◆ Always design the flap in fusiform fashion so that superior and inferior tabs are inserted into the anastomosis. This splits up the suture line, reducing circumferential stenosis.
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal. Sew a second layer if possible. With pectoralis or lower-island trapezius flaps, a portion of the muscle may be used as the second layer.
- ◆ Assess the neck for closure and pressure on the regional flap pedicle in the tunnel. If closure is too tight, we prefer to skin graft the muscle. Make sure the tunnel is wide enough to accommodate the flap pedicle and any additional swelling that will occur postoperatively.
- ◆ If the reconstruction of stricture or defect is in the low cervical esophagus, be prepared to remove the clavicle and manubrium if using a pectoralis myocutaneous flap. This maneuver may be necessary to reduce the torque and allow the proper rotation of the skin paddle into the defect.

Option for Management: Radial Forearm Free Flap

The radial forearm free flap is the authors' preferred method for most cervical esophageal reconstructions. It is thin and

pliable, and adequate tissue can be harvested for partial or circumferential defects. The blood supply is robust and the reduced bulk leads to fewer strictures.

Surgical Technique and Considerations

- ◆ Tracheostomy is typically not needed unless the patch defect extends close to the hypopharynx.
- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a gastrostomy tube is not in place.
- ◆ Enter the stricture vertically or assess the defect and decide the necessary tissue to adequately augment the lumen. We prefer a 3 cm diameter lumen in ideal scenarios, which equates to approximately 9 cm in circumference. Subtracting the size of the existing tissue from 9 cm will give the tissue measurement needed.
- ◆ Prior to harvesting the forearm flap, ensure that adequate vessels are present for the anastomosis.
- ◆ Place the flap into the defect and assess for proper geometry. An external monitor may be used by turning out a segment of the skin. If it is not used, we typically align the pedicle in the midline so that Doppler assessment of the flap can be performed postoperatively and not confused with the carotid artery.
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal.

Option for Management: Jejunal Free Flap

Jejunal flaps provide mucus-secreting, peristaltic tissue to patch or replace the cervical esophagus. Ample jejunum may be harvested to accommodate any cervical esophageal defect. The radial forearm free flap has largely replaced this flap, but some surgeons still prefer to use the jejunum. If a patient has a poor Allen's tests bilaterally, then the jejunum is a reasonable option if the patient is healthy enough to tolerate the procedure. The laparotomy does increase the morbidity and mortality of the procedure, but many general surgeons are using the laparoscope to harvest the segment of bowel for the flap.

Surgical Technique and Considerations

- ◆ Nasogastric tubes are not necessary as the patient will typically have a J-tube placed during the procedure.
- ◆ Prior to disconnecting the jejunum, ensure that adequate vessels are present for the anastomosis. Quick microvascular anastomosis is critical with the jejunum (less than 90 minutes). The jejunum does not tolerate long periods of ischemia. We perform the microvascular anastomosis prior to inset.
- ◆ Mark the distal bowel so that proper orientation can be maintained to ensure proper food propulsion and prevent regurgitation and persistent dysphagia.
- ◆ Place the flap into the defect and assess for proper geometry. An external monitor or implantable Doppler

is recommended with jejunal flaps, as these are some of the most sensitive flaps to ischemia.

- ◆ The external monitor may be removed after 5 to 7 days at bedside.
- ◆ The flap can serve as a patch by opening the antimesenteric side and sewing this into the defect.
- ◆ Use an anastomotic stapler or interrupted Vicryl sutures to ensure a watertight seal.

Patient Selection and Perioperative Management

Following reconstruction of the esophagus, the patient is NPO for a minimum of 5 to 7 days prior to initiation of oral feeding. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube if present. If there is concern about a leak, we obtain a swallow study to document the location and quality of the leak and resume NPO status.

◆ THE CIRCUMFERENTIAL DEFECT FOR CERVICAL ESOPHAGUS

The ideal reconstruction of the cervical esophagus is one that re-creates a lumen that can allow normal deglutition and a safe wound. Without continuity, the patient needs a cervical pharyngostomy and a gastrostomy tube. This significantly impacts patients' quality of life. There are many methods to reconstruct circumferential esophageal defects, but we prefer the radial forearm free flap for defects limited to the cervical esophagus. If a fasciocutaneous free flap (RFFF or anterolateral thigh) is not available, then a jejunal free flap should be considered. If the distal portion of the defect is within the chest, the authors tend to favor a gastric transposition to avoid a suture line leak in the chest. Another final option is a colonic interposition, but we rarely use this anymore.

Option for Management: Radial Forearm Free Flap

The radial forearm free flap is the authors' preferred method for most cervical esophageal reconstructions. It is thin and pliable, and adequate tissue can be harvested for partial or circumferential defects. The blood supply is robust and the reduced bulk leads to fewer strictures.

Surgical Technique and Considerations (Fig. 5.10)

- ◆ Tracheostomy is typically not needed unless the patch defect extends close to the hypopharynx.
- ◆ We prefer to tube the flap over a salivary bypass tube for circumferential defects while still in the arm and vascularized.
- ◆ We prefer a 3-cm diameter lumen in ideal scenarios, which equates to approximately 9 cm in circumference. Prior to harvesting the forearm flap, ensure that adequate vessels are present for the anastomosis.

- ◆ Place the flap into the defect and assess for proper geometry. An external monitor may be used by turning out a segment of the skin. If it is not used, we typically align the pedicle in the midline so that Doppler assessment of the flap can be performed postoperatively and not confused with the carotid artery.
- ◆ We break up the proximal and distal suture lines with V-shaped tabs by de-epithelializing the RFFF upon inset.
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal.

Option for Management: Jejunal Free Flap

Jejunal flaps provide a mucus-secreting, peristaltic tissue to patch or replace the cervical esophagus. Ample jejunum may be harvested to accommodate any cervical esophageal defect. The radial forearm free flap has largely replaced this flap, but some surgeons still prefer to use the jejunum. If a patient has a poor Allen's tests bilaterally, then the jejunum is a reasonable option if the patient is healthy enough to tolerate the procedure. The laparotomy does increase the morbidity and mortality of the procedure but many general surgeons are using the laparoscope to harvest the segment of bowel for the flap. The mortality is approximately 3%, but the morbidity ranges from 40 to 54% based on a review of a current large series that consists of cervical reconstructions of the esophagus and laryngopharynx.¹² Hyperperistalsis can result in dysphagia in many patients.

Surgical Technique and Considerations

- ◆ Nasogastric tubes are not necessary, as the patient will typically have a J-tube placed during the procedure.
- ◆ Prior to disconnecting the jejunum, ensure that adequate vessels are present for the anastomosis. Quick

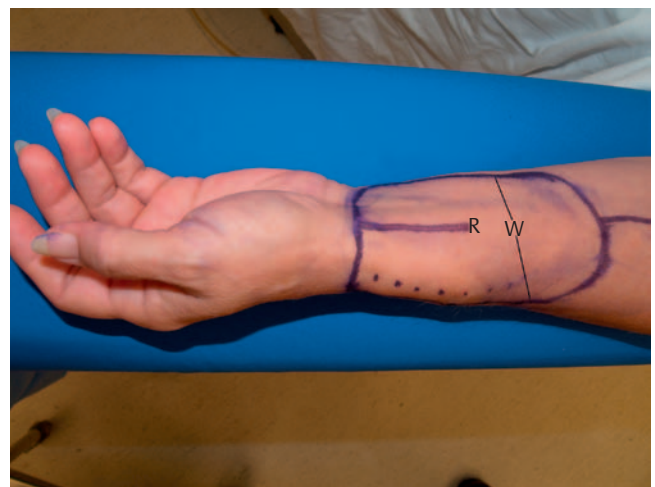


Fig. 5.10 Radial forearm free flap for circumferential esophageal defect. The width (W) is 9 cm and the length is designed to the superior, inferior dimensions of the defect. Dashed line, cephalic vein; R, radial artery.

microvascular anastomosis is critical with the jejunum (less than 90 minutes), because the jejunum does not tolerate long periods of ischemia. We perform the microvascular anastomosis prior to inset.

- ◆ Mark the distal bowel so that proper orientation can be maintained to ensure proper food propulsion and prevent regurgitation and persistent dysphagia.
- ◆ Place the flap into the defect and assess for proper geometry. An external monitor or implantable Doppler is recommended with jejunal flaps, as these are some of the most sensitive flaps to ischemia.
- ◆ The external monitor may be removed after 5 to 7 days at bedside.
- ◆ Use an anastomotic stapler or interrupted Vicryl sutures to ensure a watertight seal.

Option for Management: Gastric Transposition

Defects that extend into the thoracic cavity are best reconstructed with a gastric transposition, otherwise known as a gastric pull-up procedure. This procedure is done in conjunction with our thoracic surgeon colleagues. Circumferential flaps can be sewn in place, but it is preferable not to have an anastomosis within the thoracic cavity. Gastric transpositions result in one cervical anastomosis and is based on the right gastric and gastropiploic vessels. The left gastric and short gastric vessels are ligated. A pyloromyotomy is performed to enhance food passage. The thoracic surgeon typically places a jejunostomy tube at the time of the surgery. The stomach is passed through the posterior mediastinum. The main issue with this flap is the need for three-visceral compartment dissection—neck, thorax, and abdomen—which inherently increases morbidity and mortality. In-hospital mortality from the procedure is approximately 9%, with a morbidity of 50% consisting of mostly minor complications. Anastomotic leak occurs in approximately 10%.¹³

Surgical Technique and Considerations

- ◆ Nasogastric tubes are not necessary as the patient will typically have a J-tube placed during the procedure.
- ◆ Most gastric pull-ups can reach the defect, but occasionally additional tissue may be needed to bridge the gap if the stomach cannot reach.
- ◆ Use a gastrointestinal (GI) stapler for the anastomosis if possible. If this is not available or feasible, use interrupted Vicryl sutures to ensure a watertight seal.

Patient Selection and Perioperative Management

Following reconstruction of the esophagus, the patient is NPO for a minimum of 5 to 7 days prior to initiation of oral feeding. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube if present. If there is concern about a leak, we obtain a swallow study to document the location and quality of the leak and resume NPO status.

◆ THE LARYNGOPHARYNGEAL DEFECT

The laryngopharyngeal defect lends itself to many different reconstructive options. Primary closure is the optimal scenario if adequate tissue is available. Hui et al¹⁴ studied the minimum amount of residual pharynx necessary for closure and swallowing. They found that patients with narrow widths of 1.5 to 2.5 cm resumed an oral diet. In a later study, the same group demonstrated no swallowing differences in patients closed primarily with a pharyngeal remnant width of 3 cm.¹⁵ Anastomotic staplers may be used to assist with closure, which inherently provides a more watertight seal than sewing (**Fig. 5.11**).

If the defect is not circumferential but additional tissue is needed, free tissue transfer does not have a major benefit over the PM flap in most individuals **Fig. 5.12**. If a patient is overweight or had previous breast or chest wall surgery, the PM flap may not be an option. Circumferential defects can be closed with a PM flap, but free flaps are better in this scenario. We prefer the radial forearm free flap in circumferential defects. A jejunum is a suitable option but it requires an abdominal procedure, which increases the morbidity and mortality of the operation. If a large amount of anterior neck skin is needed, the anterolateral thigh (ALT) free flap is a great option to both re-create a tube and resurface the neck skin. The RFFF cannot replace as much skin as an ALT can in circumferential defects with significant skin requirements. Even if the tumor does not involve the skin, it may be difficult to close the neck in a chemoradiated patient. We tend to place salivary bypass tubes in chemoradiated patients and remove them in 3 weeks if the wounds are healing well.



Fig. 5.11 Stapler-assisted closure of a noncircumferential laryngopharyngeal defect. We prefer to use a right-angled stapler. Typically it is a TA 90 or 60, 2-row stapling instrument.

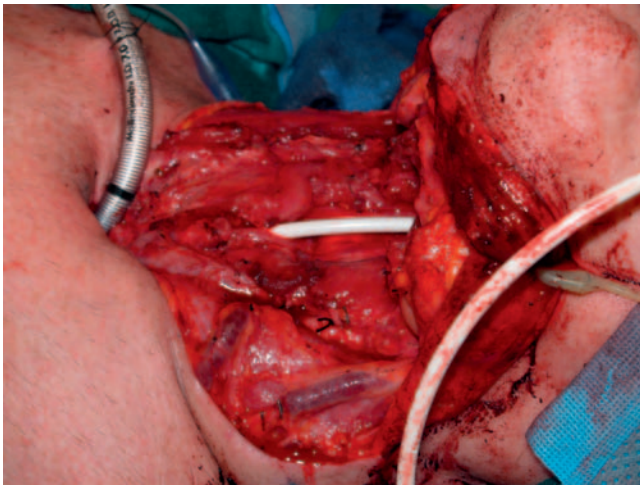


Fig. 5.12 Noncircumferential laryngopharyngeal defect that requires closure with additional tissue.

Option for Management: Pectoralis Myocutaneous Flap

The PM flap is a versatile, reliable, robust flap that is quickly raised and results in little morbidity for the patient. Selection of appropriate candidates is important, as a large body habitus or previous chest wall surgery can preclude using this flap or make its use challenging. The cutaneous paddle in women with pendulous breasts can be less reliable, so caution should be taken while harvesting PM flaps in women. The PM flap is good for noncircumferential defects. Circumferential defects can be reconstructed with this flap but is not as reliable and flexible as tubed free flaps.

Surgical Technique and Considerations

- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a percutaneous endoscopic gastrostomy (PEG) tube is not in place.
- ◆ After the margins are cleared, measure the defect and design an appropriate-size cutaneous paddle over the pectoralis muscle.
- ◆ We favor making our lateral incision and finding the lateral edge of the muscle (**Fig. 5.13**). We then define the distal portion of the muscle prior to making the superior and inferior incisions. The skin paddle can be altered (inferior/superior plane) based on the distal extent of the muscle. Always put the skin over the muscle and avoid shearing forces during the harvest.
- ◆ Assess the neck for closure and pressure on the regional flap pedicle in the tunnel. If closure is too tight, we prefer to skin graft the muscle. Make sure the tunnel is wide enough to accommodate the flap pedicle and any additional swelling that will occur postoperatively (**Fig. 5.14**).
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal. Sew a second layer if possible. A portion of the muscle may be used as the second layer.

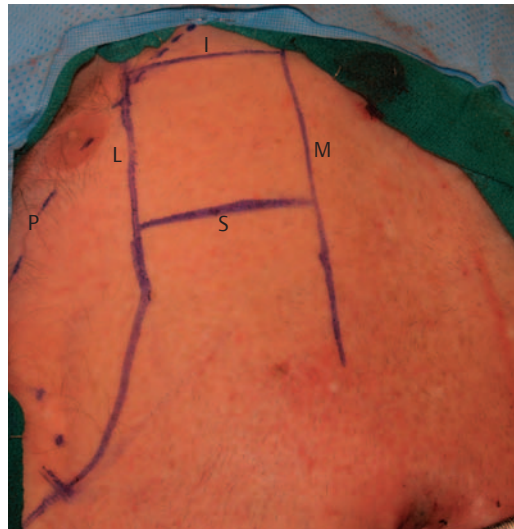


Fig. 5.13 Pectoralis myocutaneous flap design.

- ◆ If a regional flap is the only option and the patient has a large habitus, we will raise muscle only for PM flaps and skin graft the muscle to provide a thinner reconstruction.
- ◆ If the defect is circumferential and a free flap is not a good option, the skin paddle can be sewn to the pharynx, prevertebral fascia laterally, and esophageal stump distally. The posterior edge of the pharynx and esophageal stump must be secured to the prevertebral fascia. The other option is to raise bilateral PM flaps and oppose the two skin paddles to create a tube.

Option for Management: Radial Forearm Free Flap

The radial forearm free flap is the authors' preferred method for circumferential laryngopharyngeal defects or when the patient has too large a body habitus for a pectoralis major myocutaneous flap. It is thin and pliable, and adequate tissue

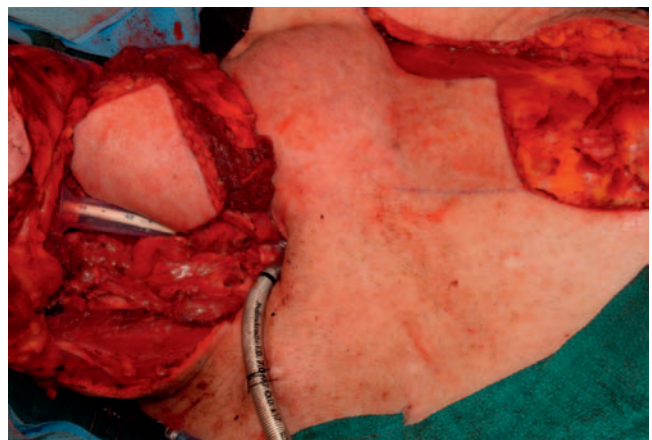


Fig. 5.14 Harvest of the flap, and tunneled underneath into the neck.

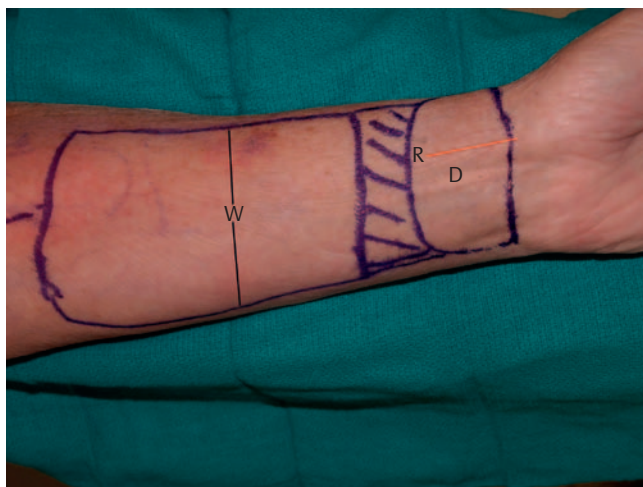


Fig. 5.15 Radial forearm free flap for circumferential laryngopharyngeal defect. Hashed lined demarks area to be de-epithelialized so the distal tab (D) will be rotated out and incorporated into the superior stoma. It serves to reduce tension on the neck closure and as an external monitor. Tabs to break up the anastomotic suture line are designed on inset. W, width (9 cm); R and red line, radial artery.

can be harvested for partial or circumferential defects. The blood supply is robust, and the reduced bulk leads to fewer strictures. It can also provide some tissue to the anterior neck, particularly in chemoradiated patients whose necks are difficult to close (**Fig. 5.15**).

Surgical Technique and Considerations

- ◆ We prefer to place a salivary bypass tube in chemoradiated patients with circumferential defects. Secure the tube to a red rubber catheter brought through the nasopharynx to the nose and sutured to the septum (**Fig. 5.16**). The other option is to secure it to the base of tongue with nonabsorbable heavy suture.
- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a gastrostomy tube is not in

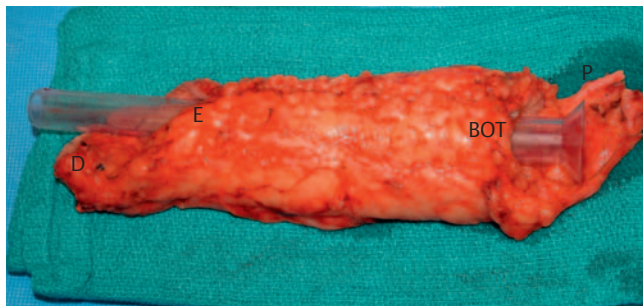


Fig. 5.16 Radial forearm fasciocutaneous free flap (RFFF) tubed over a Montgomery salivary bypass tube and ready for inset. Secure the tube to a red rubber catheter or to the base of tongue as described. BOT, sutured to the base of tongue; D, distal tab rotated out to augment stoma and act as an external monitor; E, sutured to the esophageal stump; P, pedicle.

place. This will go through the salivary bypass tube.

- ◆ We prefer a 3-cm diameter lumen in ideal scenarios, which equates to approximately 9 cm in circumference. This could be the width of the flap for circumferential defects, as in. The flap can also be closed in a spiral fashion with a narrower flap.
- ◆ Prior to harvesting the forearm flap, ensure that adequate vessels are present for the anastomosis.
- ◆ Place the flap into the defect and assess for proper geometry. An external monitor may be used by turning out a segment of the skin. If it is not used, we typically align the pedicle in the midline so that Doppler assessment of the flap can be performed postoperatively and not confused with the carotid artery.
- ◆ We break up the distal suture line with V-shaped tabs by de-epithelializing the RFFF upon inset.
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal.

Option for Management: Anterolateral Thigh Free Flap

The ALT flap is the authors' preferred method of reconstructing circumferential laryngopharyngeal defects when a large portion of the skin needs to be replaced. Its thickness varies depending on the patient's habitus (**Fig. 5.17**). It can be raised perforator-based to reduce the muscle harvested. The flap can also be thinned significantly. One of the primary advantages of this flap is the minimal donor-site morbidity compared with that of all the other flaps. Even with large ALT flaps with tight closures and sacrifice of some vastus lateralis muscle, the patients tolerate it well. If the ALT is not available and there is a significant external defect, a gastro-omental flap is a decent option. The omentum is excellent at restoring the external skin if needed, but it does require a laparotomy, increasing the morbidity and mortality of this surgery.

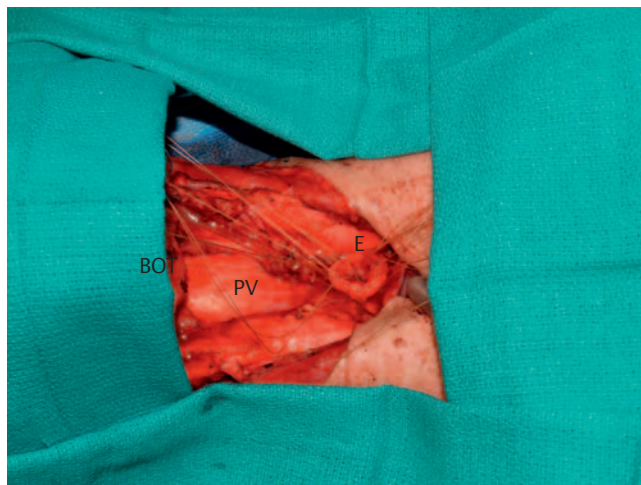


Fig. 5.17 Large laryngopharyngeal defect with the need for a significant amount of external skin. BOT, base of tongue; E, esophageal stump; PV, prevertebral fascia.

Surgical Technique and Considerations (Figs. 5.18–22)

- ◆ We prefer to place a salivary bypass tube in chemoradiated patients with circumferential defects (**Fig. 5.16**). Secure the tube to a red rubber catheter brought through the nasopharynx to the nose and sutured to the septum. The other option is to secure it to the base of tongue with nonabsorbable heavy suture.
- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a PEG tube is not in place. This will be fed through the salivary bypass tube.
- ◆ Design the flap in a large ellipse shape after locating the perforators. The medial–lateral distance should equal the defect length from superior to inferior.
- ◆ De-epithelialize two strips of the flap approximately 9 cm apart. Sew the de-epithelialized segments together to form a central tube and external skin paddles in the form a smaller ellipse. We do this over the salivary bypass tube in chemoradiated patients.
- ◆ Place the flap into the defect and assess for proper geometry. An external monitor is naturally present when resurfacing the skin. If it is not used, we typically

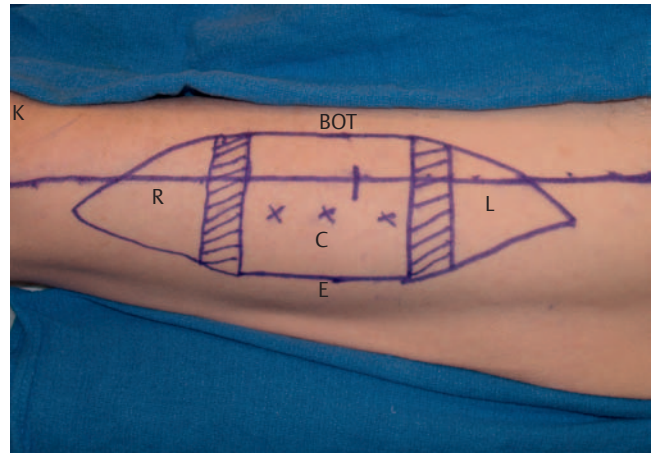


Fig. 5.18 Anterolateral thigh free flap design for the defect. x, perforators in center of flap; hashed marks, de-epithelialized portion, which is sewn to the opposite de-epithelialized portion; BOT, sutured to base of tongue; C, center of new pharyngoesophageal lumen; E, sutured to esophageal stump; K, knee; L, left external cutaneous portion; R, right external cutaneous portion; tabs to break up the anastomotic suture line are designed on inset.

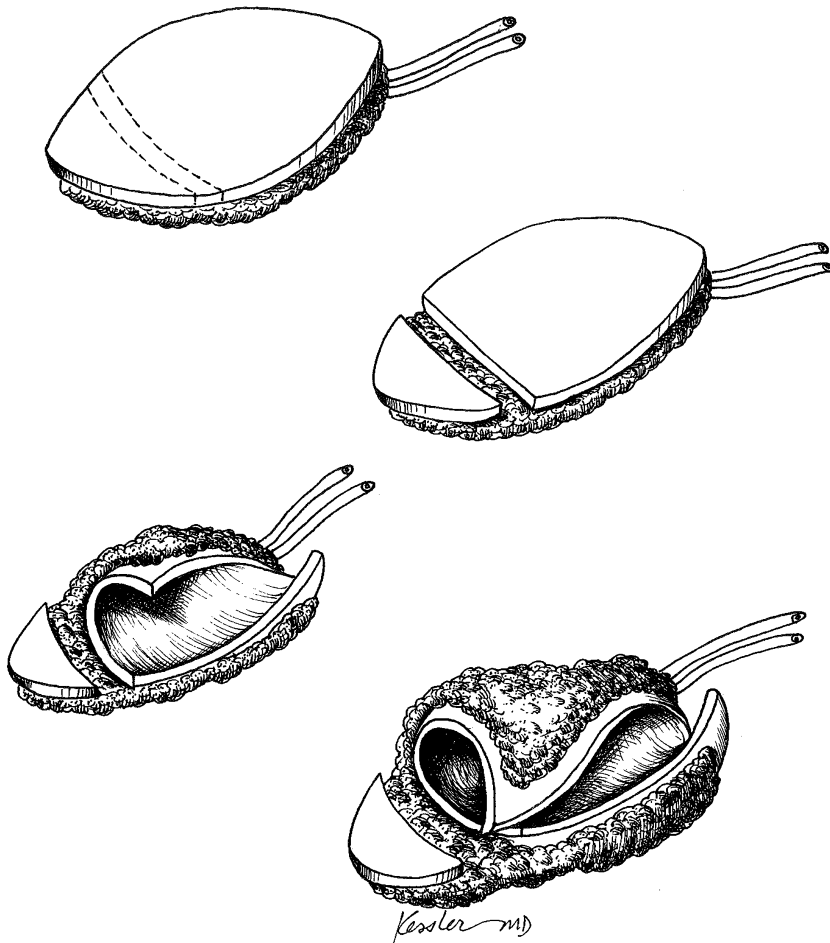


Fig. 5.19 Illustration of the design for an anterolateral thigh flap when used in the conical design. The advantage of this design is a larger circumference to accommodate the upper base of tongue and pharynx closure.

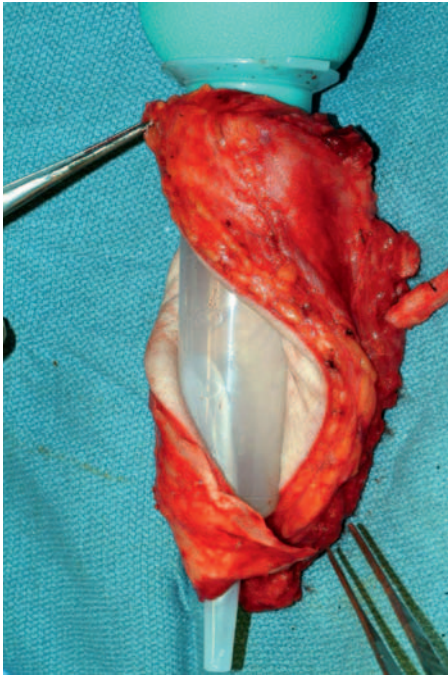


Fig. 5.20 The skin paddle is placed around a plastic stent to demonstrate the design.

align the pedicle in the midline so that Doppler assessment of the flap can be performed postoperatively and not confused with the carotid artery.

- ◆ We break up the distal suture line with V-shaped tabs by de-epithelializing the ALT upon inset (**Fig. 5.22**).
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal.

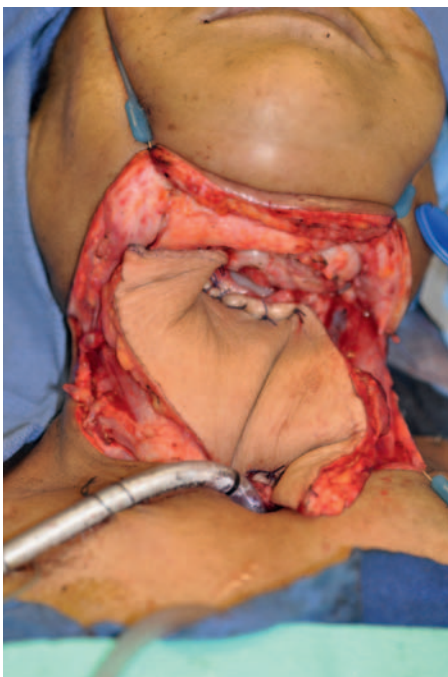


Fig. 5.21 The conical design flap placed into the pharyngeal defect.

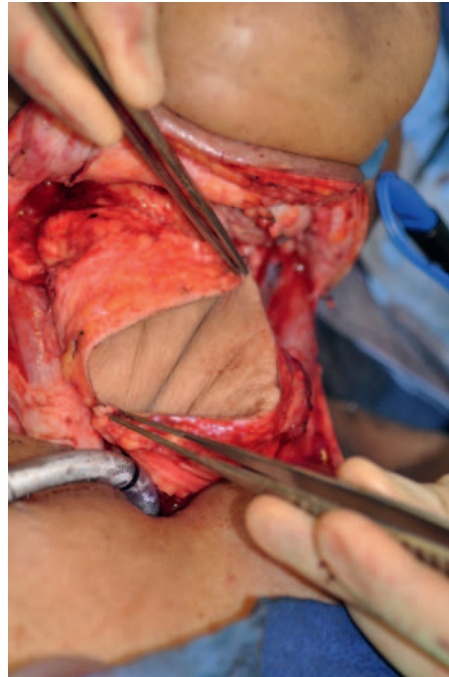


Fig. 5.22 The skin paddle is folded to provide closure of the defect.

Option for Management: Jejunal Free Flap

Jejunal flaps provide a mucus-secreting, peristaltic tissue to patch or replace the cervical esophagus and pharynx. Most defects can be reconstituted with the pectoralis or radial forearm free flap, so a jejunum is our third choice. The radial forearm free flap has largely replaced this flap, but some still prefer to use the jejunum. If a patient has a poor Allen's tests bilaterally, then the jejunum is a reasonable option if the patient is healthy enough to tolerate the procedure. The laparotomy does increase the morbidity of the procedure, but many general surgeons are using the laparoscope to harvest the segment of bowel for the flap. The mortality is approximately 3%, but the morbidity ranges from 40 to 54% based on a review of a current large series that consists of cervical reconstructions of the esophagus and laryngopharynx.¹⁶ Hyperperistalsis can result in dysphagia in many patients.

Surgical Technique and Considerations

- ◆ Nasogastric tubes are not necessary, as the patient will typically have a J-tube placed during the procedure.
- ◆ Prior to disconnecting the jejunum, ensure that adequate vessels are present for the anastomosis. Quick microvascular anastomosis is critical with the jejunum (less than 90 minutes). The jejunum does not tolerate long periods of ischemia. We perform the microvascular anastomosis prior to inset.
- ◆ Mark the distal bowel so that proper orientation can be maintained to ensure proper food propulsion and prevent regurgitation and persistent dysphagia.

- ◆ Place the flap into the defect and assess for proper geometry. An external monitor or implantable Doppler is recommended with jejunal flaps as these are some of the most sensitive flaps to ischemia.
- ◆ Spatulate the proximal end to accommodate the pharyngeal lumen anastomosis.
- ◆ The external monitor may be removed after 5 to 7 days at bedside.
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal.

Option for Management: Gastric Transposition

Defects that extend into the thoracic cavity are best reconstructed with a gastric transposition, otherwise known as a gastric pull-up procedure. This procedure is done in conjunction with our thoracic surgeon colleagues. Circumferential flaps can be sewn in place, but it is preferable not to have an anastomosis within the thoracic cavity. Gastric transpositions result in one cervical anastomosis and is based on the right gastric and gastroepiploic vessels. The left gastric and short gastric vessels are ligated. A pyloromyotomy is performed to enhance food passage. The thoracic surgeon typically places a jejunostomy tube at the time of the surgery. The stomach is passed through the posterior mediastinum. The main issue with this flap is the need for three-visceral compartment dissection—neck, thorax, and abdomen—which inherently increases morbidity and mortality. In-hospital mortality from the procedure is approximately 9%, with a morbidity of 50% consisting of mostly minor complications. Anastomotic leak occurs in approximately 10%.¹⁷

Surgical Technique and Considerations

- ◆ Nasogastric tubes are not necessary, as the patient will typically have a J-tube placed during the procedure.
- ◆ Most gastric pull-ups can reach the defect, but occasionally additional tissue may be needed to bridge the gap if the stomach cannot reach.
- ◆ Use a GI stapler for the anastomosis if possible. If this is not available or feasible, use interrupted Vicryl sutures to ensure a watertight seal.

Patient Selection and Perioperative Management

Following reconstruction of the laryngopharynx, the patient is NPO for a minimum of 5 to 7 days prior to initiation of oral feeding. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube if present. If there is concern about a leak, we obtain a swallow study to document the location and quality of the leak.

◆ THE COMBINATION DEFECT–TRACHEA

The surgical treatment of tracheal neoplasms, stomal recurrences, larynx tumors with significant subglottic extension, thyroid cancers, and cervical esophageal neoplasms may

result in the difficult combination defect of the laryngopharynx and trachea. Anticipation of this potential defect is necessary to ensure that the appropriate thoracic colleagues are present for assistance if needed. Reconstruction of the esophageal and hypopharyngeal components is the same as outlined earlier in this chapter. Tracheal reconstruction becomes a problem when it cannot reach the skin or if it puts pressure on the innominate artery. The constant pressure and movement of the artery can result in a trachea-innominate fistula, which is a disastrous complication with a high morbidity and mortality. The surgeon should assess for pressure on the artery and decide if interposing tissue (PM flap, local sternocleidomastoid muscle flap) is needed or if an anterior mediastinal tracheostomy or slide tracheoplasty should be performed. Orringer¹⁸ agrees that a minimum 5-cm distal stump of trachea is considered mandatory for adequate reconstruction with an anterior mediastinal tracheostomy (AMT). The morbidity and mortality is significant with this procedure, and patients should be counseled prior to the operation regarding the risks. If the distal tracheal stump is less than 5 cm, then a slide tracheoplasty may be necessary to obtain enough length to perform a tracheostoma or AMT. This involves reimplantation of the right mainstem bronchus distally to the left mainstem bronchus to provide more length on the trachea.

Orringer¹⁹ now prefers to perform colonic interposition flaps in tracheoesophageal reconstructions that require an AMT to avoid the pharyngogastric anastomosis and subsequent long-term unpleasant side effects of this procedure (regurgitation). In his series, pharyngogastric anastomosis resulted in leaks in over a third of patients, which can be troublesome with an AMT.

Option for Management: Anterior Mediastinal Tracheostomy

The goals of an AMT are (1) to establish a tracheostoma, and (2) to eliminate tension or pressure on the innominate artery. Participation with an experienced thoracic surgeon is imperative for this procedure to be successful. The basic principle is to move the tracheal stump inferior and lateral to the innominate artery to reduce tension. Elective innominate artery ligation is rare currently, and rerouting of the tracheal stump should be performed initially.

Surgical Technique and Considerations

- ◆ Assess the tracheal stump after negative surgical margins are obtained. It must be at least 5 cm. If shorter, a slide tracheoplasty may be needed to obtain the proper length.
- ◆ Plan a PM flap or free flap for superior stomal coverage. Once the trachea is rerouted inferior to the artery, there is always exposed artery and tissue that the neck skin will not cover.
- ◆ A PM cutaneous paddle replaces the skin defect superior to the stoma, and the muscle with or without fat should be interposed between the artery and trachea, even if

there appears to be little or no contact between the two.

- ◆ The breast plate will need to be resected in an area to accommodate the tracheostoma.
- ◆ There must be no tension on the artery from the tracheostoma at the end of the procedure, and always interpose vascularized tissue (regional or free) between the new tracheostoma and innominate vessels.

Patient Selection and Perioperative Management

Following reconstruction of the trachea, the patient is NPO for a minimum of 7 days prior to initiation of oral feeding. Any bleeding should be investigated as a sentinel bleed until proven otherwise. A tracheoinnominate fistula should be ruled out. The patient typically requires ventilator assistance for 1 to 2 days postoperatively. Hypoparathyroidism is a common problem of this defect and is often permanent. Involvement of an endocrinology colleague is recommended. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube if present. If there is concern about a leak, we obtain a swallow study to document the location and quality of the leak.

◆ RECONSTRUCTION OF THE HYPOPHARYNX WITH AN INTACT LARYNX

The hypopharyngeal defect with an intact larynx is an unusual circumstance but challenging for the reconstructive surgeon. The primary concern is aspiration, as the larynx is still present. Tissue transfer, regional or free, results in an insensate segment of the hypopharynx. The optimal reconstruction provides adequate lumen and sensation for passage of food and fluid. For transoral laser resection defects that do not communicate with the neck, we prefer to allow the defect to granulate and remucosalize. This is the ideal scenario and typically the best outcome for swallowing. Once the defect communicates with the neck, the surgeon should consider primary closure or augmentation with vascularized tissue. Primary closure should be tension free and provide adequate lumen for passage of food and liquids. Most regional flaps are too bulky for this defect, so if primary closure is too tight or impossible, we prefer the radial forearm free flap. A PM flap is possible only if the patient lacks significant subcutaneous tissue and muscle bulk. Placing a bulky tissue reconstruction in this area often results in significant dysphagia and aspiration. Successful hypopharyngeal reconstruction also depends on the presence of at least one functioning internal branch of the superior laryngeal nerve. If both nerves are sacrificed, the patient will invariably aspirate and have trouble with any reconstruction of the hypopharynx with an intact larynx. These patients often need a laryngectomy for aspiration.

Option for Management: Radial Forearm Free Flap

The RFFF is the best alternative to healing by secondary intention or primary closure. It provides thin pliable tissue that can seal the defect from the neck and restore functional deglutition. The insensate nature of the flap will improve over 6 to 18 months, but it will never be as good as native tissue. However, with the help of speech and swallow therapy, safe and adequate oral intake can resume.

Surgical Technique and Considerations

- ◆ Place a nasogastric feeding tube prior to any reconstructive efforts if a PEG tube is not in place.
- ◆ Prior to harvesting the forearm flap, ensure that adequate vessels are present for the anastomosis.
- ◆ Make sure the lumen of the new hypopharynx that is created is not too large, as it will lead to the pooling of secretions. Measure the defect and plan the flap to the exact dimensions to avoid overcorrecting the hypopharyngeal diameter.
- ◆ Place the flap into the defect and assess for proper geometry. These are buried flaps, but a separate cutaneous paddle may be used and incorporated into the incision. If it is not used, we typically align the pedicle near the midline so that Doppler assessment of the flap can be performed postoperatively and so that it will not be confused with the carotid artery.
- ◆ Use interrupted Vicryl sutures to ensure a watertight seal.

Patient Selection and Perioperative Management

Following reconstruction of the hypopharynx, the patient is NPO for a minimum of 5 to 7 days prior to initiation of oral feeding. We resume oral intake under the care of an experienced speech and swallow therapist, and different patient-activated maneuvers will be necessary to regain function. Once the patient reaches adequate oral intake to maintain nutrition and there is no evidence of a leak, we pull the nasogastric tube if present. If there is concern about a leak, we obtain a swallow study to document the location and quality of the leak and resume NPO status.

◆ VOICE AND SWALLOW REHABILITATION

The quality of life of these patients is significantly affected by the cancer, treatments, and reconstructions. The presence of a PEG tube is the single most significant factor that negatively impacts a head and neck cancer patient's quality of life.²⁰ Although the primary goal of the reconstructive surgeon is to create a safe wound, the restoration of normal deglutition is also important. After successful healing of a reconstruction, the patient should receive swallowing

therapy from a dedicated head and neck–trained speech pathologist. Therapy is imperative to restoration of adequate, safe swallowing in many of these reconstructions. Voice restoration is also an important aspect in patients who lose their larynx as part of treatment. Reconstruction is fairly straightforward and can significantly impact the patient's quality of life.

Option for Management: Tracheoesophageal Puncture

Restoration of speech is an important tool to consider even at the primary surgery. For patients undergoing a laryngopharyngectomy, if the reconstruction does not extend to the potential tracheoesophageal puncture (TEP) site, we will usually perform a primary tracheoesophageal puncture. Caution should be taken with primary TEP in chemoradiated patients, as the fistula rate is significantly higher in this group.²¹ We perform primary TEP only in native mucosa. We perform secondary TEPs in all of the other flaps if the patient desires it at a later date. It is more difficult in thicker reconstructions. TEP in jejunal free flap patients for laryngopharyngectomy defects was successful in approximately 75% of patients in multiple series.^{22,23} The drawback is a wet-sounding voice due to mucus production and tissue flaccidity. If there is any concern about performing a primary TEP, delay the procedure and perform it secondarily. An electro-larynx should be given to the patient and its proper use taught by the speech pathologist.

◆ CONCLUSION

Reconstruction of the pharynx, soft palate, cervical esophagus, and hypopharynx can pose a significant challenge to the head and neck reconstructive surgeon. The first basic principle is to create a safe wound to prevent fistula formation, great vessel rupture, and death. Restoration of normal deglutition is the primary functional outcome we should attempt to achieve, as this has the most significant impact on the patient's quality of life. The surgeon should replace the tissue with a reconstruction consisting of health vascularized alternative that is close to the original tissue. Appropriate patient selection and operative planning is imperative for successful outcomes in these patients.

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6

Skull Base Reconstruction

K. Kelly Gallagher, John R. de Almeida, Eric M. Genden, and Douglas B. Chepeha

Advances in reconstructive techniques have enabled improved functional outcomes after ablative skull base surgery. Reconstruction of cranial base defects involves separating the sterile cranial cavity from a contaminated upper aerodigestive tract, middle ear/mastoid, and orbits. Paramount to this task is obtaining a watertight seal of the dura to prevent potential intracranial complications such as meningitis and intracranial abscess. Perioperative radiotherapy can compromise wound healing, lead to resorption of non-vascularized tissues, and predispose patients to wound infections. In the setting of benign disease or when perioperative radiotherapy is not necessary, reconstruction may be more straightforward often requiring only local flaps or in some cases nonvascularized tissue. However, the addition of radiation provides additional considerations in reconstructive decision making. The concept of a reconstructive ladder, utilizing local, regional, or free tissue for the increasing extent of defect, is a model that may not apply in skull base defects, because the best reconstructive option is the one that will be most effective in preventing complications. Neligan et al¹ showed that free flaps have substantially fewer wound complications than local and regional flaps (10% versus 20.4% and 36.3%, respectively). Similarly, free flaps are associated with lower rates of cerebrospinal fluid (CSF) leaks, meningitis, and abscess. Pedicled myocutaneous flaps such as the pectoralis major flap often cannot reach the skull base and may suffer from distal necrosis, resulting in the aforementioned complications. Smaller defects may require free tissue transfer in the setting of radiation, in the case of revision surgeries, and when dead space must be obliterated.

More recent advances in the endoscopic approach to skull base extirpation have been paired with novel techniques in endoscopic reconstruction and may lead to a reconstructive approach from the nasal cavity as opposed to from the cranial cavity. The reconstructive surgeon may take advantage of a different armamentarium of reconstructive options for this approach. Regardless of whether an open or endoscopic approach to reconstruction is utilized, the principles

are still the same: to create a stable barrier to separate a sterile cranium from a contaminated upper aerodigestive tract.

◆ RELEVANT ANATOMY

The skull base is composed of five bones: the frontal, ethmoid, sphenoid, occipital, and parietal. It is further divided into regions that house different components of the brain known as the anterior, middle, and posterior cranial fossae. The anterior cranial fossa is bounded anteriorly by the frontal bones and posteriorly by the anterior clinoid processes and the planum sphenoidale. The crista galli, a vertical projection of the ethmoid bone, sits in the midline. The horizontal component of the ethmoid bone is composed of the cribriform plate through which the olfactory filaments descend into the nasal cavity and the fovea ethmoidalis. Laterally the frontal bones compose the orbital roof. Communications between the cranium and the sinonasal cavity such as the foramen cecum and the olfactory foramina may provide a potential route for the spread of infection.

The middle cranial fossa is bounded anteriorly by the greater wing of the sphenoid, which also forms the anterior floor. The petrous temporal bone makes up the posterior floor of the middle fossa. Centrally the greater wing of the sphenoid makes the sella turcica bounded anteriorly by the anterior clinoid processes and posteriorly by the posterior clinoid processes. The floor of the middle cranial fossa has numerous foramina through which cranial nerves exit the cranium.

The posterior cranial fossa is composed of the sphenoid, occipital, and temporal bones. Anterior to the foramen magnum, the sphenoid and occipital bones form the bony clivus. Posteriorly, the occipital bone medially meets the posterior petrous temporal bone to make up the floor of the posterior fossa.

◆ CLASSIFICATION OF SKULL BASE DEFECTS

The ideal classification system is one that would categorize defects according to reconstructive options. Such a classification system has not yet been developed. The difficulty in developing this classification system relates to the anatomic complexity of the skull base, the variability of the defects, and the need to strike a balance between making the system simple enough for effective communication by clinicians but complex enough to be useful as a defect-based decision-making tool.

Jackson and Hide² initially described a classification of skull base lesions that has largely been replaced by a schema introduced by Jones et al³ in which anterior, middle, and posterior regions correlate to the anterior, middle, and posterior cranial fossae. Irish and colleagues⁴ reviewed 77 patients with skull base neoplasms and further classified tumors into skull base regions (I, II, and III) based on anatomic boundaries and tumor growth patterns (**Fig. 6.1**). Region I tumors arise from the sinuses, orbit, and nasal cavity and extend to involve the anterior cranial fossa. Region II tumors also include those that arise from the clivus and extend posteriorly to the foramen magnum. Region III tumors originate in the lateral skull base and extend into the infratemporal and pterygopalatine fossa with involvement of the middle cranial fossa. Region III lesions arise from the ear or parotid or temporal bone and extend intracranially to

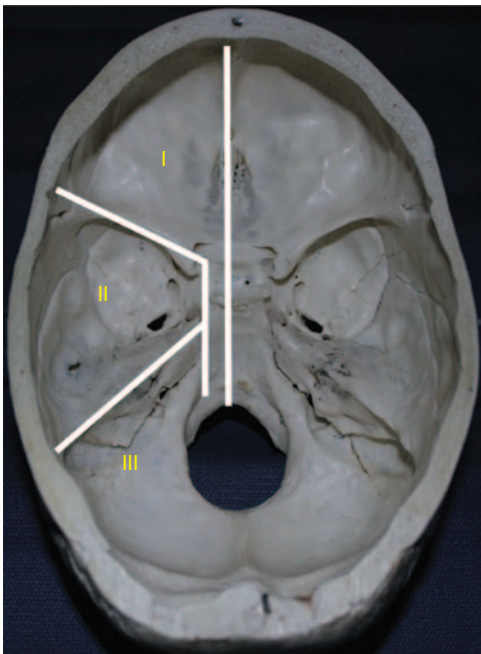


Fig. 6.1 Irish classification. The skull base has been described by Irish et al⁴ to be divided into three regions based on the anatomic location and growth pattern of skull base tumors. Region I involves the anterior skull base. Region II tumors originate in the lateral skull base and extend into the infratemporal and pterygopalatine fossa with involvement of the middle cranial fossa. Region III lesions arise from the ear, parotid, or temporal bone and extend intracranially to involve the posterior cranial fossa.

Table 6.1 The Mount Sinai Classification of Skull Base Defects (Modified)

I	Dura	Intact Primary repair Patch graft
II	Mucosa	Nasal-nasopharyngeal Oro-opharyngeal Sphenoid
III	Skin	Scalp Forehead Midface Lower face Neck Auricle
IV	Bone	Calvaria Zygoma Palate Mandible Orbital floor Temporal
V	Cavities	Cranial Sinonasal Orbital Oral

Note: In this classification system, skull base defects are defined according to elements that have an impact on morbidity and functional outcome to compare the reconstruction of defects of similar extent. The five types of defects that are most commonly reconstructed are shown.

involve the posterior cranial fossa. This classification is useful for describing the specific area of the skull base that requires reconstruction.⁵⁻⁸

More recently, the Memorial Sloan-Kettering group described a classification system that includes defects of the anterior and middle cranial base.⁹ The anterior base defects are categorized as a simple or complex resection. Simple defects include the skull base at the cribriform plate adjacent to a tumor, which may include removal of a portion of the palate or the orbital contents. Complex defects include the floor of the anterior cranial fossa adjacent to the lesion, dura, or brain, with or without orbital contents, and the nasal cavity, maxilla, and the palate.

The most sophisticated description of skull base defects was developed by the Mount Sinai group (**Table 6.1**).¹⁰ This classification system takes into account the individual anatomic elements that are involved in skull base defects. It includes seven major defect categories: (1) dura, (2) bone, (3) cutaneous, (4) mucosal, (5) cavity, (6) neurologic, and (7) carotid artery. These defect categories serve as a framework to guide the reconstructive surgeon to avoid potential morbidity. Dural defects closed primarily are at lower risk than those that require a patch graft after dural resection. Similarly, more extensive mucosal defects may predispose one to the introduction of secretions that may contaminate the CSF. Cranial nerve deficits may affect both functional and cosmetic outcomes. The classification system is very useful for

Anterior Skull Base Reconstructive Schema

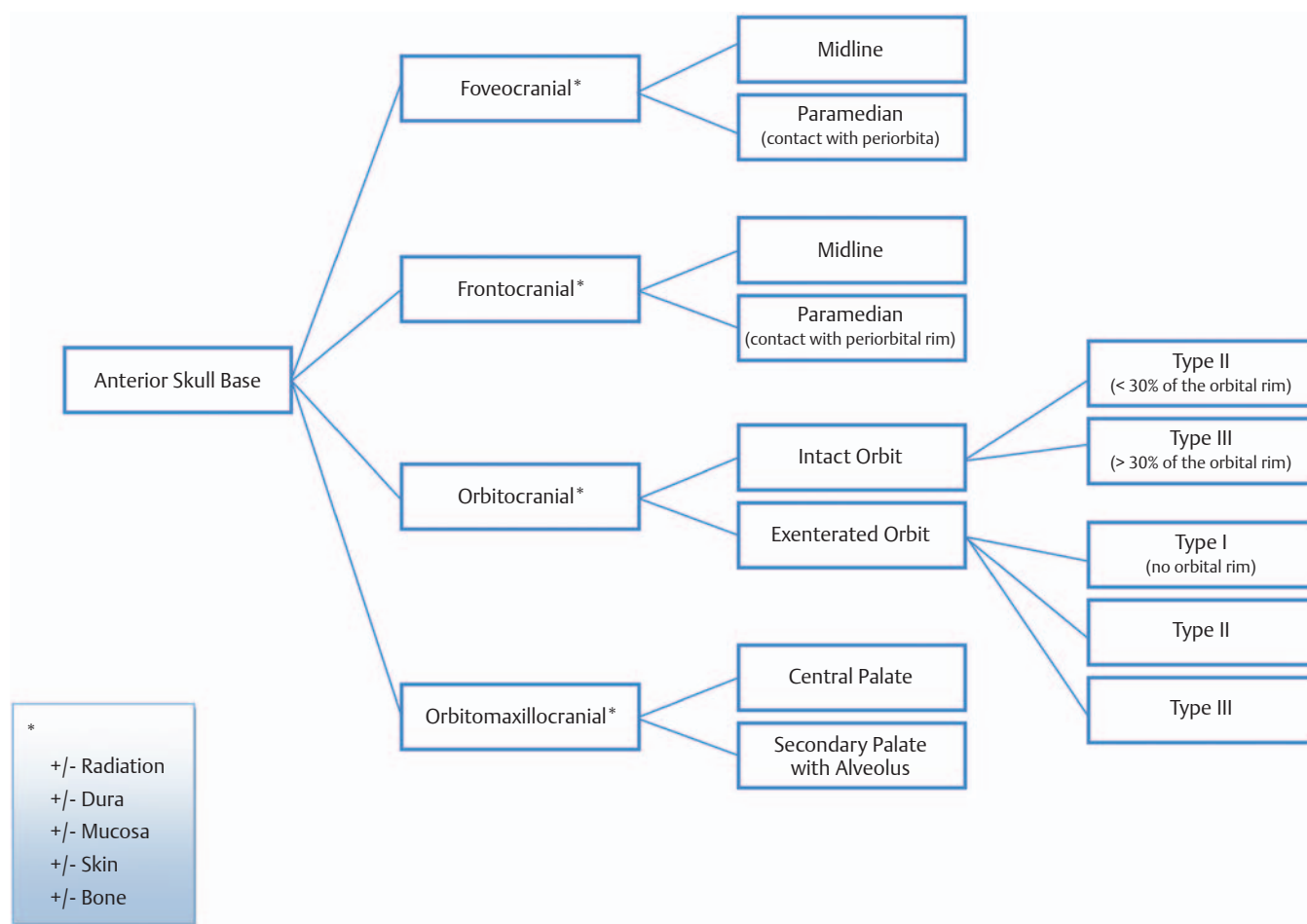


Fig. 6.2 Skull base reconstructive schema. This schema defines the discrete locations of the skull base defect in combination with key functional aspects of the skull base in an effort to guide reconstructive planning.

providing a detailed description of the defect, giving detailed analysis for decision making, predicting potential postreconstructive complications, and in counseling patients.

For general clinical use, we use a classification involving subdivision of the anterior cranial fossa defects into compartments that direct the reconstructive algorithm; these regions are foveocranial, frontocranial, orbitocranial, and orbitomaxillocranial (**Fig. 6.2**).

◆ FOVEOCRANIAL DEFECTS

Foveocranial defects are median or paramedian defects involving the ethmoid bone or the inner table of the frontal bone. Defects involving the orbit laterally or outer table of the anterior frontal bone do not qualify for this category of defects. Because the frontal and orbital rims remain intact, reconstruction of foveocranial defects often requires soft tissue coverage alone. Reconstruction of this area is focused on separation of the cranial compartment from the nasal

cavity with a prerequisite watertight dural seal and use of vascularized tissue to prevent CSF leak and intracranial infectious complications. Before the use of local vascularized flaps, reconstruction of skull base defects consisted principally of split-thickness skin graft coverage. The importance of vascularized tissue was realized as Ketcham et al¹¹ reported that approximately 50% of patients with skin grafts or tensor fascia lata grafts developed CSF leaks. Since that time, the use of pericranial and galeal flaps has shown superior results with regard to prevention of CSF leak and infection. Tumors in this location are well suited to endoscopic approaches, and innovations with local pedicled flaps have facilitated more reliable reconstruction.

Prior to consideration of local, regional, or free flap coverage, one must ensure adequate dural closure. If the defect is small, a primary closure can be considered. With larger defects, Snyderman et al¹² advocate the use of a sandwich-type approach for closure. A synthetic dural substitute can be used as an underlay graft between the dura and brain. The dura itself can be reconstructed with fascial grafts such as tensor fascia lata, synthetic acellular dermis, or in some

cases pericardium. This then can be sutured to achieve a watertight closure or alternatively secured using U-clips—a deployable suture based on shape-memory metal. Although these techniques are relatively reliable in the nonradiated patient, the radiated patient represents a unique challenge. The compromise in tissue vascularity means that tissue healing is compromised. This is compounded in a previously operated field. Patients with a history of radiotherapy require special consideration and the liberal use of vascularized tissue whenever possible to enhance healing.

Option for Management: Nasoseptal Flap

Recent advances in transnasal expanded endoscopic approaches have allowed for better visualization and a larger scope of resection of skull base lesions. Reconstruction of larger defects previously required a separate external approach with its associated morbidity. Hadad and colleagues¹³ introduced a novel technique using a vascularized pedicled nasoseptal flap (Hadad-Bassagasteguy flap) that allows entirely endoscopic reconstruction of larger skull base defects. Hirsch¹⁴ in 1952 initially described a random septal flap for endoscopic repair of a CSF leak with the constraint of a broad base that limited rotation of the random flap. In contrast, the nasoseptal flap utilizes blood supply from the posterior nasoseptal artery.

Multiple series have demonstrated success with the nasoseptal flap for repair of CSF leaks and reconstruction of skull base defects after extended endoscopic approaches.^{13,15,16} The superiority of the nasoseptal flap over septal flaps performed in previous decades is attributed to its superior arc of rotation and large surface area. The risk of postoperative CSF leak from skull base ablative procedures reconstructed with the nasoseptal flap has decreased to approximately 5%, comparable with that of open reconstructive techniques.¹⁵ More recently, the nasoseptal flap has been utilized in a “reuse” manner for cranial base defects and adds to its versatility as a reconstructive option for expanded endoscopic resection of skull base lesions. This “takedown technique” for patients who require additional ablative surgery or for planned staged surgery has reasonably good success.¹⁷ In the case of tumor recurrences one should exercise caution in using the “takedown” technique.

Surgical Technique and Considerations

- ◆ The blood supply to the nasoseptal flap is the posterior septal branch of the sphenopalatine artery.
- ◆ Prior to the procedure, adequate exposure can be achieved by decongesting the nose with topical adrenaline, and often resection of the middle turbinate is necessary to provide access to the tumor and for the reconstruction.
- ◆ A needle-tip monopolar cautery or contact laser is used for the mucoperichondrial incisions starting with the posteroinferior incision along the choana and extending along the inferior septum. The posterosuperior incision is placed through the natural sphenoid os and extends

superiorly (1 cm below the cranial base to avoid damage to olfactory mucosa), whereas the inferior incision travels along the maxillary crest aspect of the septum. A wider flap may be harvested by extending the inferior septal incision to include the mucoperiosteum of the nasal floor. The two septal incisions are then joined anteriorly by a vertical incision.

- ◆ Prior to elevation of the flap, detaching the fibers at the front wall of the sphenoid and rostrum with a Cottle elevator can ease flap elevation.
- ◆ A submucoperichondrial plane is used for the dissection.
- ◆ The flap can be stored in the nasopharynx or in an enlarged natural maxillary sinus ostium for the duration of the procedure to avoid interfering with tumor resection.

Patient Selection and Perioperative Management

Careful consideration should be given to patients with tumors involving the septal mucosa. The nasoseptal flap is typically raised at the onset of the procedure, and one should not compromise oncologic principles to use this flap. A careful plan of the ablative cuts should be determined prior to raising the flap if the tumor is in proximity of the flap.

Perioperatively, the reconstruction is often bolstered by either nasal packing or a Foley catheter inflated with sterile water. The Foley catheter can be deflated between day 1 and day 7, depending on the extent of the resection and the surgeons concern of stability of the reconstruction. The denuded nasal septum is left to granulate and can typically take roughly 3 months to remucosalize.¹⁸ Rigorous follow-up by the endoscopic surgeon for debridement as well as aggressive nasal hygiene using saline rinses will facilitate return to normal nasal function.

Option for Management: Pericranial Flap

The subgaleal fascia is deep to the galea. When the subgalea is raised with the periosteum of the skull, it is termed the pericranial flap. The use of a pericranial flap was first reported by Wolfe¹⁹ and expanded by Johns et al²⁰ in a series of four patients with craniofacial defects. This dense vascularized connective tissue was found to be a practical reconstructive option given the access already employed in the bicoronal approach for ablative skull base surgery. In initial applications of the pericranial flap, skin grafts were used to line the nasal side of the flap. Snyderman et al²¹ subsequently reported that low complication rates were achieved without skin grafts in a review of 30 patients whose anterior cranial base defects were reconstructed with pericranial flaps alone. The pericranial flap has proven to be very reliable when used in limited anterior skull base reconstruction with minimal donor-site morbidity. The risk of CSF leak after reconstruction using this flap has been consistently reported to be approximately 5%. The flap is thin, pliable, and reported to be well vascularized even after regional irradiation. If the pericranial flap is available, particularly with open

approaches, it is the best option for supporting a dural closure and separating the cranial and nasal cavities in foveo-cranial defects. Some authors have proposed that a more robust blood supply can be obtained if the galeopericranial flap is elevated.²² Including the galea may only marginally increase the distal blood supply of the pericranial tissue, and dissection of galea from the overlying skin can result in cutaneous necrosis. For these reasons the galea is rarely incorporated because readily available, unirradiated, autogenous tissue can be transplanted into the defect.

Surgical Technique and Considerations

- ◆ The pericranial flap is based on the supraorbital and supratrochlear arteries (**Fig. 6.3**).
- ◆ Harvest of the pericranial flap involves elevation in the subgaleal plane down to the level of the supraorbital rims. In the supraorbital region, the supraorbital notch is identified and the supraorbital vascular bundle is freed (**Fig. 6.4**).
- ◆ If a foramen is present, a 4-mm osteotome can be used to preserve the neurovascular bundle and maintain the arterial supply to the flap.
- ◆ The periosteum is then transversely incised 10 to 15 cm superior to the supraorbital rims and the flap elevated inferiorly beyond the supraorbital rim. It is protected anteriorly while osteotomies and tumor extirpation are performed (**Fig. 6.5**).
- ◆ At the time of reconstruction, the pericranial flap is placed intracranially after the supraorbital bone is re-secured to allow for coverage of the frontal bar in anticipation of adjuvant radiation (**Fig. 6.6**).

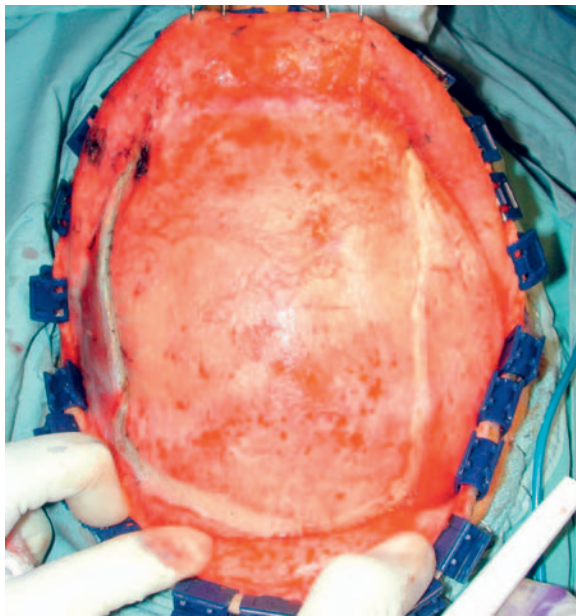


Fig. 6.3 The pericranial flap (top view). The pericranial flap can be designed to according to the size of the defect. Large defects or the need for extra tissue to obliterate a “dead space” can be managed by dissecting a large flap.

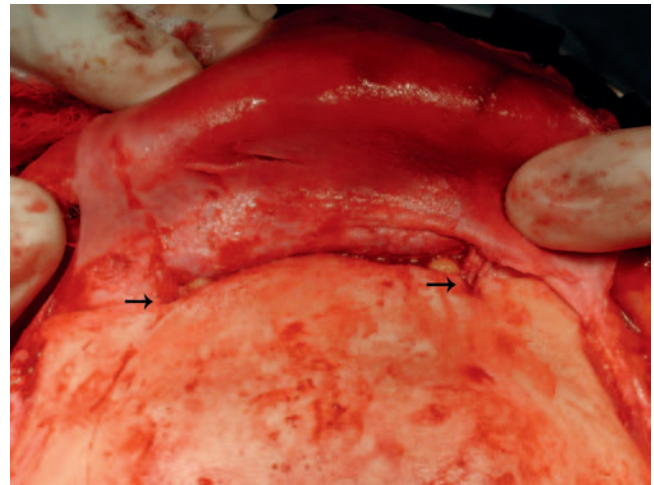


Fig. 6.4 The neurovascular bundle (top view). The neurovascular bundle should be identified and preserved. If it arises from a distinct foramen, the foramen can be released with an osteotome to improve rotation of the flap.

- ◆ In cases of revision surgery or frontal lobe atrophy, the volume between the frontal dura and cranial side of the frontal bone becomes great enough that one cannot be confident that the reconstruction will heal without infection or necrosis. In these circumstances, autogenous tissue transplantation is indicated.
- ◆ For endoscopic cases, the pericranial flap can be elevated through a minimally invasive approach using two small scalp incisions measuring 2 cm and 1 cm, and one transverse glabellar incision measuring 1 cm. The flap can be raised endoscopically with an elevator



Fig. 6.5 The pericranial flap elevated (top view). The flap is well vascularized and will easily reach the frontal skull base to repair defects of this region.

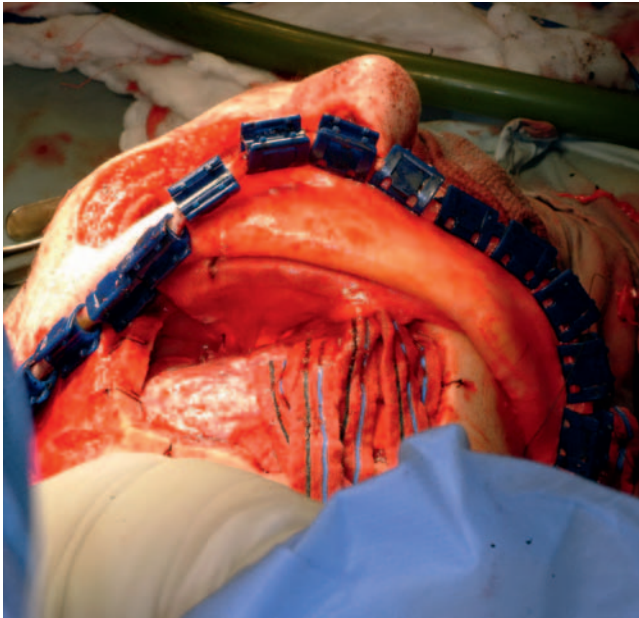


Fig. 6.6 The flap is placed into the frontal defect (top view). Then the closure should be performed by creating small drill holes along the defect's bony periphery to anchor the pericranial flap.

through one incision and an endoscope through the second scalp incision. Through the glabellar incision, a nasal through-and-through osteotomy can be created using a cutting burr to transpose the flap intranasally.²³ Further investigation is still required to understand the overall effectiveness and utility of this approach.

Patient Selection and Perioperative Management

The pericranial flap is ideal for large foveocranial defects that require vascularized coverage of the defect. Its use can also be extended to provide vascularized tissue to surround free grafts, as will be discussed later in this chapter. The minimally invasive pericranial flap is ideal for patients who undergo endoscopic procedures in whom a nasoseptal flap is precluded for oncologic reasons. Perioperative care involves appropriate wound care for the bicoronal incision and other nasal hygiene measures applicable to the nasoseptal flap.

Option for Management: Temporoparietal Fascia Flap

The temporoparietal fascia flap (TPFF) has been utilized extensively in head and neck reconstruction. Fortes et al²⁴ describe a technique in which the TPFF is delivered into the nasal cavity through a temporal-infratemporal soft tissue tunnel and transpterygoid window. This approach was reported in two patients without postoperative CSF leak and without complication. Harvested from the lateral parietal skull, the flap has a rich vascular supply based on the superficial temporal vessels.



Fig. 6.7 The incisions for the temporoparietal flap harvest. The incision used to harvest the temporoparietal flap is a Y-incision or a hemicoronal incision to gain access to the flap and provide the maximum exposure.

Surgical Techniques and Considerations (Figs. 6.7 and 6.8)

- ♦ The temporoparietal fascial flap is supplied by the superficial temporal artery and vein.
- ♦ A coronal incision is made with care in the preauricular region to avoid injuring the vascular pedicle as it travels superficially anterior to the helical root.



Fig. 6.8 The flap can be applied to orbitocranial and nasal frontal defects as a pedicled flap, but can also be used as a free flap if necessary.

- ◆ A subdermal elevation is required along the coronal incision just beneath the hair follicles. This can result in overlying skin loss if excessive electrocautery is used.
- ◆ The anterior fascial incision must be posterior to the frontal branch of the facial nerve to avoid paralysis.
- ◆ To communicate the flap intranasally, an endoscopic transpterygoid approach is needed to open the contents of the pterygopalatine fossa. The external flap is communicated internally by first releasing the temporalis from the lateral orbital wall through a lateral canthus incision. Tracheal dilators are then used to open a space and transpose the flap intranasally.²⁴

Patient Selection and Perioperative Considerations

In previously operated patients with a healed coronal incision, the vascular pedicle may be compromised, precluding the use of this flap. This flap may be used more frequently in endoscopic sinus surgery cases as an alternative to the nasoseptal flap in cases where this flap is unavailable due to previous use or tumor involvement.

Option for Management: Palatal Island Flap

When a nasoseptal flap is unavailable, a palatal island mucoperiosteal flap may be transposed into the nasal cavity through limited enlargement of a single greater palatine foramen. This flap was popularized by Gullane and Arena²⁵ for palatal reconstruction. Oliver et al²⁶ have demonstrated the use of this flap in skull base reconstruction for defects of the planum, sella, and clivus. The feasibility of such a flap was shown through cadaver dissections, but further evidence is needed to prove its effectiveness in reconstruction.

Surgical Techniques and Management

- ◆ The blood supply to the palatal island flap is the greater palatine artery and vein.
- ◆ Design of the flap should ensure adequate coverage of the skull base defect. Oliver et al²⁶ suggest as much as 12 to 18 cm² defects can be covered by this flap.
- ◆ The pedicle can be as long as 3 cm, but mobilization of the flap can be facilitated by opening the palatine foramen using a small osteotome.
- ◆ Dissection of the flap is in the submucoperiosteal plane.
- ◆ Careful orientation of the flap should avoid twisting of the vascular pedicle.
- ◆ Delivery to the skull base is performed by enlarging the greater palatine foramen and delivery of the flap.

Patient Selection and Perioperative Management

Like the temporoparietal flap, this flap can be used in instances when the nasoseptal flap is unavailable for use. In the immediate postoperative setting, patients can be started

on a liquid diet for 2 days followed by a pureed diet for 2 days to allow for healing. Donor-site care involves oral hygiene with antiseptic mouth rinses. Remucosalization of the donor site occurs over the course of 4 to 6 weeks postoperatively.

Option for Management: Facial Artery Mucosal Muscular (FAMM) Flap/Facial Buccinator Flap

The FAMM flap has been described in cadaveric feasibility studies but has yet to be employed in clinical practice. The Pittsburgh group described the use of this flap in skull base reconstruction.²⁷ Described as the facial buccinator flap, this musculomucosal flap can be rotated 180 degrees and delivered into the nasal cavity through a maxillary window. It may have potential utility for reconstruction after expanded endoscopic approaches to skull base lesions, but further studies are required to prove its effectiveness in patients.

Option for Management: Fasciocutaneous Free Tissue

The radial forearm fasciocutaneous free flap (RFFF) is an excellent option for low-volume reconstructions if local and regional tissues are not available. This donor site is reliable, has a long vascular pedicle, provides thin pliable tissue, and has been shown to be effective for closing CSF leaks.^{28,29} Despite its widespread application, the reports of its use in anterior skull base reconstruction are more limited but show it to be a favorable option. In a study of 10 patients with defects from anterior or lateral skull base lesions, reconstruction with the radial forearm flap led to no flap failures or infections and only one CSF leak.³⁰ At the University of Michigan, Chepeha et al³¹ reported that 20 patients undergoing salvage surgery of the anterior skull base after previous surgery or radiation were reconstructed with radial forearm free tissue and had a low rate of CSF leak (5%) and low overall major complication rate (15%). Potential disadvantages of the radial forearm free flap over local flaps include a longer operative time and additional low risk of hand morbidity. Other fasciocutaneous or myogenous flaps may be utilized and designed to fit the foveocranial defect when the volume of the radial forearm donor site is not sufficient to fill the defect.

Surgical Techniques and Considerations

- ◆ The radial forearm flap is based on the radial artery and its venae comitantes (**Fig. 6.9**).
- ◆ An appropriate donor site should be selected in the nondominant hand of the patient and care should be taken in the preoperative setting to avoid intravenous cannulation of that arm.
- ◆ During the ablative approach, care should be taken to preserve the superficial temporal vessels for subsequent anastomosis. Where these vessels are not available, one should consider using the facial artery as the donor



Fig. 6.9 The orbital nasal defect. While the orbital nasal defect requires separation of the nasal and orbital cavities, minimal volume is required so that the orbital cavity can accommodate an orbital prosthesis at a later date.

vessel with or without the use of vein grafting to achieve adequate pedicle length (**Fig. 6.10**).

- ◆ A template of the ablative defect should be created prior to harvesting the flap to ensure adequate tissue (**Fig. 6.11**).
- ◆ The flap pedicle can be brought out anteriorly through the bifrontal or subcranial craniotomy and tunneled



Fig. 6.10 Sutures are placed peripherally around the bony nasal vault help to anchor the skin paddle and separate the orbit from the nasal cavity.



Fig. 6.11 A double skin paddle radial forearm flap can be used to partition the individual cavities.

subcutaneously to reach the donor vessels. Care must be taken to ensure adequate room for the vascular pedicle and to avoid pressure on the pedicle after closure of the wound (**Fig. 6.12**).

- ◆ In cases where the frontal bone is resected for oncologic reasons, an osseocutaneous radial forearm free flap can be used for reconstruction (**Fig. 6.13**).

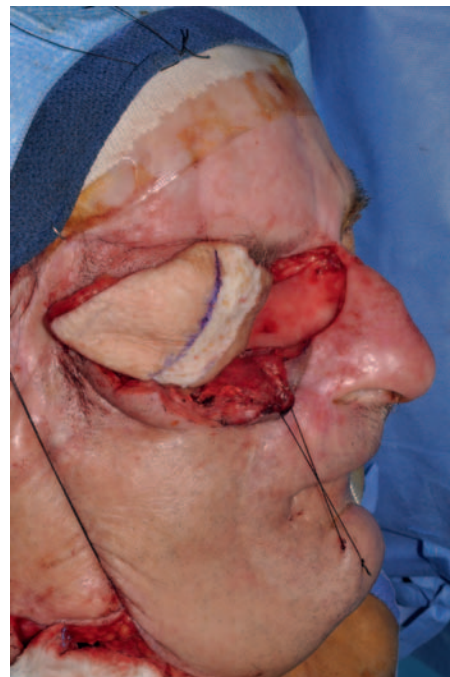


Fig. 6.12 The distal skin paddle is used for nasal lining. The proximal paddle is used to line the orbit.



Fig. 6.13 The 1-year postoperative result demonstrates a well-healed orbital cavity.

Patient Selection and Perioperative Management

When a large area of vascularized soft tissue is needed for reconstruction, and pericranium is not available or provides inadequate coverage, this is a strong reconstructive option. In the postoperative setting, the arm should be splinted in the position of safety for a period of 7 days, and donor defects should be skin grafted when necessary. Occasional numbness to the dorsum of the hand can result from radial sensory nerve injury using this flap. Meticulous nasal hygiene should be instituted using saline irrigations and endoscopic debridement as necessary.

◆ FRONTOCRANIAL DEFECTS

Reconstruction of frontocranial defects requires either vascularized soft tissue of adequate bulk or a bony construct. A principal concern for frontocranial defects is sufficient obliteration of the potential dead space that may exist between dura and the frontal bone. If the frontal or scalp skin is missing, this surface must also be addressed. Soft tissue can obliterate space, but if muscle is used it will atrophy and decrease the volume of the reconstruction. The missing portions of the frontal bone—the floor, posterior table, anterior table, or brow—also direct the reconstructive algorithm. In general, a defect of the frontal brow greater than 4 cm should be reconstructed with vascularized bone in a patient who will undergo radiation or has already undergone radiation, unless significant patient comorbidities preclude the longer operative time. It has been demonstrated that patients with a history of prior skull base surgery or radiation have a lower risk of major postoperative complications related to salvage

surgery when reconstructed with a vascularized autogenous transplant.³¹

Option for Management: Pericranial Flap with Bone Graft

The pericranial flap is the reconstruction of choice if local tissue is available and the patient does not have a history of radiation. In radiated patients, selective use of the pericranial flap is recommended for small defects. Defects can be reinforced using split calvarial bone. If this bone has been radiated, however, it is better to use a nonradiated donor site in the parietal region. Some authors show excellent results using pericranium to wrap nonvascularized bone grafts.^{32–34} In a series of 34 patients who were reconstructed with split calvarial bone graft wrapped in pericranium, 33 grafts survived.³⁵ The authors concluded that defects measuring more than 3.0 cm × 4.0 cm should be reconstructed rigidly with bone grafts. The single graft failure was related to osteomyelitis and epidural abscess in a patient who had been treated with radiation. Sinha et al³⁶ reported successful results in 20 patients with anterior skull base defects who were not radiated prior to surgery and were reconstructed with a “three-layer technique” in which the first layer is titanium mesh against dura followed by calvarial bone grafts; the two layers are then wrapped in a pericranial flap.³⁶ Six of the patients were radiated postoperatively and none of the patients developed a CSF leak, infection, or exposure of grafts after at least 1 year of follow up. We suggest that these techniques are useful for radiated patients with bone defects less than 4 cm in length or 6 cm².

Surgical Technique and Considerations

- ◆ Split calvarial bone grafts can be harvested from the outer table of the cranium after raising a bicoronal skin flap and pericranial flap or by harvesting the inner table of a bone flap from a craniotomy. Grafts should be harvested in nonradiated areas to improve the chances of graft take (**Fig. 6.14**).
- ◆ For grafts from the outer table, a cutting burr is used to create an outline of the bone graft to be harvested. Care must be taken to avoid full-thickness cuts and dural injury (**Fig. 6.15**).
- ◆ A smaller burr can then be used to undermine the outer cortical bone by drilling in cancellous bone. A curved osteotome can then be used with careful bone cuts to avoid fracturing the graft or penetrating the inner table (**Fig. 6.16**).
- ◆ The graft is then wrapped in vascularized pericranium and placed into position or can be harvested as a pedicled vascularized bone graft.

Patient Selection and Perioperative Management

Patients should be carefully selected for use of nonvascularized tissue. Heavily irradiated areas or areas of planned



Fig. 6.14 The temporoparietal flap osteocutaneous flap. The flap is raised with a skin paddle, vascularized cranial bone graft, and temporoparietal fascia. The technique shown on the orbital rim is similar to the technique that can be applied to the frontocranial defect.

irradiation can compromise graft take, although wrapping nonvascularized bone may facilitate healing. These grafts typically do not result in much pain. Perioperative nasal hygiene regimens should be followed as previously discussed.



Fig. 6.15 The vascularized bone is pedicled on the temporoparietal fascia.



Fig. 6.16 The osseofasciocutaneous paddle is used to resurface the infraorbital defect, and the bone and fascia are used to reline the orbito-skull base defect.

Option for Management: Fasciocutaneous-, Myocutaneous-, or Perforator-Based Free Flaps

Soft tissue free flaps are an option for obliterating cranial base defects. The fasciocutaneous radial forearm autogenous transplant is a good option when the volume of the frontocranial defect is small, whereas the anterolateral thigh (ALT) autogenous transplant is a good option for larger defects. This donor site also contains ample fascia that can be used for dural repair. The fascia can remain vascularized for dural closure, but this has not been found to be necessary. Chana et al³⁷ reported a series of seven patients reconstructed with ALT free tissue in which there were no CSF leaks or meningitis after a mean follow-up of 10 months.

Historically, the rectus abdominis autogenous transplant is the donor site of first choice in skull base reconstruction.^{38–40} The vascular pedicle anatomy is reliable, and large amounts of skin, fat, muscle, and fascia can be transferred. The muscle may help with wound healing problems, including osteoradionecrosis. In these cases it can be harvested as a musculo-fascial transplant. The large bulk of this flap may be a disadvantage if the defect size is not extensive.

The latissimus dorsi is useful as a myocutaneous donor site for defects that are medium to high surface area or wounds that are poorly vascularized. These include patients with multiple surgeries, a history of radiation, plans for reirradiation, or known osteoradionecrosis. The flap is composed of a relatively thin muscle layer, a relatively thin cutaneous layer, and a long vascular pedicle. Some authors attribute their preference in using the flap to the low morbidity associated with its harvest.

Surgical Technique and Considerations

- ◆ The ALT flap is based on the descending branch of the lateral circumflex femoral artery. The rectus flap is based on the deep inferior epigastric artery.
- ◆ For skull base reconstructions a long pedicle is often necessary to reach recipient vessels. To maximize the length of the ALT vascular pedicle, a distal perforator needs to be located prior to dissection (**Fig. 6.17**). The skin paddle can be designed appropriately to have a longer vascular pedicle (up to 20 cm).^{41,42}
- ◆ The donor site of the ALT can be closed primarily, leaving the extensor muscles intact. Perforator-based harvests leave the muscle innervated at the donor site and facilitate a good functional recovery.
- ◆ If long-term precise volume contouring is desired, then the donor site can be harvested as a perforator-based transplant so that muscle atrophy will not adversely affect the reconstructed contour. The amount of fat carried with the flap can also be tailored to restore contour (**Fig. 6.18**).
- ◆ Skin can be harvested with the flap to fill cutaneous defects. The exact size of the defect has not been evaluated in studies, but in general a 3- by 4-cm defect is considered acceptable for reconstruction with soft tissue alone (**Fig. 6.19**).
- ◆ When a dural closure is required, the ALT flap can be harvested with vascularized fascia, and the rectus flap can be harvested to include peritoneum on its deep surface with a vascularized layer rather than patch graft.⁴⁰

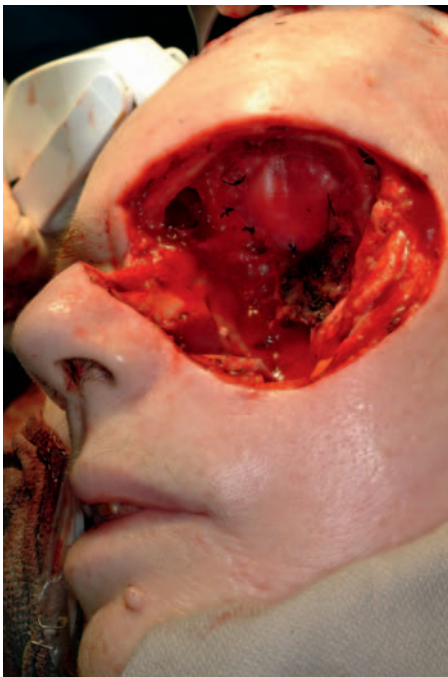


Fig. 6.17 Extensive orbital cranial defects with a defect in the dura require careful consideration. In complex orbitocranial defects, the dural defect should be addressed first. The pericranial flap represents a reliable approach to separating the cranial and orbital subunits.

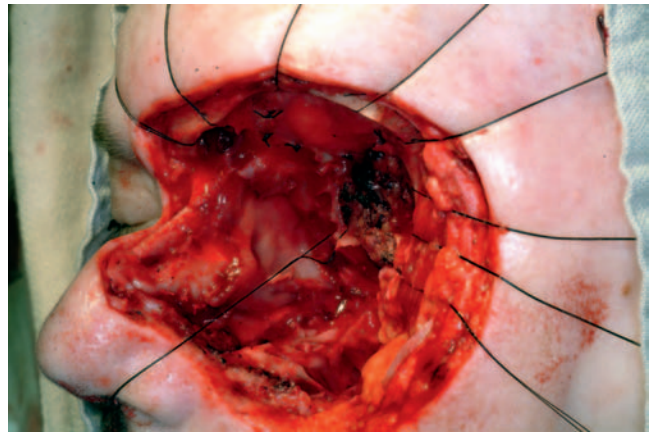


Fig. 6.18 Once the cranial and orbital cavities have been separated, the skin paddle of the flap can be designed to partition the nasal and cranial cavities. Suture can be secured to the surrounding bone to anchor the flap as a nasal and facial skin paddle are designed with an intervening area of de-epithelialized skin paddle.

- ◆ The latissimus dorsi flap affords large volumes of tissue for extensive defects. However, if the patient is muscular, the thickness of the latissimus can be problematic. The muscle will atrophy to a thickness of 2 to 4 mm in a year, which can result in contour deformity if not considered during the initial inset.
- ◆ The latissimus muscle can be positioned on the dural surface to help ensure a watertight seal, or on the bone to help prevent osteoradionecrosis. The skin paddle can also resurface large areas of the forehead and scalp. If the patient has a history of osteoradionecrosis or is going to undergo reirradiation, it is best to transfer the



Fig. 6.19 The nasal paddle is sutured into place followed by the external skin closure.

cutaneous paddle to reduce the likelihood of a wound complication.

Patient Selection and Perioperative Management

Patients with frontocranial skull base defects are well suited for fasciocutaneous and musculocutaneous flaps. Perioperative care involves active surveillance for wound breakdown, flap failure, and potential CSF leak. Donor-site management varies by flap choice. The rectus donor site places the patient at risk for ventral hernia. The risk of hernia should be lower, particularly when perforator-based harvests are performed and the fascia is conserved. The latissimus dorsi flap is associated with high rates of seroma and hematoma. Suction drains may help prevent these complications.

Option for Management: Osseocutaneous Autogenous Transplant

Rigid bony reconstruction is required for patients with frontal bone defects involving the brow greater than 4 cm. Many authors have reported the use of free bone grafts as described earlier in this chapter. It is difficult to know when to utilize bone graft wrapped in healthy, viable pericranium versus harvesting and in-setting vascularized bone. There are no published data that evaluate critical size defects in patients who are going to undergo radiation or have undergone radiation. Our bias is to use vascularized tissue in cases that are higher risk, such as patients who have undergone radiation or will receive postoperative radiation. In our opinion osseocutaneous free tissue transfer provides better wound healing, improved frontal contour, better frontal lobe protection, and entails fewer long-term complications. The key to our assumption is the high risk of resorption, extrusion, or osteoradionecrosis of free bone grafts when radiation is anticipated. The ultimate failure rate of free bone grafts in radiated fields has been reported in different series and is high despite the shorter term studies reported earlier in the chapter.^{35,43} In our opinion, free bone grafts can only be used if the bony defect is limited and supported by vascularized tissue.

◆ ORBITOCRANIAL DEFECTS

Decision making in orbital reconstruction depends on the extent of orbital rim and bony malar involvement and orbital exenteration. Orbital exenteration defects can be divided into three types.⁴⁴ Type 1 includes defects that are an orbital exenteration with an intact rim. In these patients, a fasciocutaneous or perforator based may be performed. Type 2 includes defects with involvement of less than 30% of the bony orbital rim, with or without orbital exenteration. Osseocutaneous forearm flaps can be used to restore the orbital rim when reconstructing this type of defect. Type 3 defects involve more than 30% of the bony orbital rim, with or without orbital exenteration, in addition to cheek skin or

bony malar eminence. In patients with these large orbitocranial defects, osseocutaneous scapular flaps may be used to independently address the orbital and facial defects.

When the globe is intact, the following considerations are important: closure of the periorbital, prevention of transmission of the cerebral pulse to the globe, prevention of injury to the oculomotor muscles, proper position and function of the lids, as well as attachment of the canthi and the patency of the lacrimal system. When the orbit is resected for malignancy, there is variability in the approach to restoring aesthetic and functional outcomes. A principal decision to be made in orbital exenteration defects is whether to leave the cavity open or closed. An open cavity may be reconstructed with local soft tissue flaps that separate the intracranial space from the orbital and nasal cavities, and a prosthesis can reconstruct the aesthetic contour. Closed orbital reconstruction is an approach that uses autogenous transplantation to restore the volume of the orbit, maintain surrounding skin in its normal location, and restore the periorbital bony architecture.

Clinicians disagree about the aesthetics of orbital reconstruction. Some think that an open cavity with a prosthetic is not only aesthetically better, but also shortens operating time and facilitates surveillance. Other clinicians feel that an orbital prosthesis is visually distracting because the eye and lids do not move, whereas a closed orbital reconstruction is better in social situations because it is less distracting and diverts attention to the normal eye. In addition, these same clinicians feel that a closed orbital reconstruction maintains the natural aesthetic of the remaining normal tissue, is better for wound healing, is effective in supporting radiated tissue, requires less maintenance, and does not require modeling for the placement of craniofacial implants. For patients who have undergone, or will undergo, radiation therapy, vascularized bone should be used to reduce the frequency of plate and bone exposure that is associated with free bone grafts. An open cavity can lead to surrounding tissue contracture with inferior displacement of the brow and distortion of the cheek. In most cases, a closed orbital reconstruction is thought to provide better outcomes than an open cavity and prosthesis. The decision for prosthesis is made based on the aesthetics of the patient and relies on several other factors including insurance coverage for the prosthesis, medical status, and patient activity level.

Option for Management: Prosthesis

An open cavity reconstruction with prosthesis provides the advantages of a less technically challenging surgery with a shorter operative time and the potential facilitation of tumor surveillance. The implant success rate in the orbital region is lower than the rate in the auricular and nasal areas.⁴⁵ Bone quantity and the increased failure rate in irradiated patients are the limiting factors for craniofacial implantation. There is wide variability of reported success rates of orbital osseointegrated implants: 52% for nonirradiated patients and 27% for irradiated patients in one series.⁴⁶ These findings are corroborated in other studies but with better overall success rates.^{47,48}

To provide a soft tissue framework for the prosthesis, a temporalis muscle flap can be used to rotate soft tissue into smaller volume orbital defects. Access to the flap can be gained from the bicoronal incision already utilized in the resection. Alternatively, the temporoparietal fascia flap (TPFF) has been used in a variety of head and neck defects and specifically utilized in orbital reconstruction with good success.⁴⁹ The thin, pliable flap allows for a large degree of rotation, has minimal donor site morbidity, and a large area available for harvest. Because of its dependable blood supply, the TPFF can be used to support simultaneous transfer of free or attached calvarial bone in patients who have not undergone or are going to undergo radiation. It is also useful for the coverage of craniofacial implants. The radial forearm free flap is useful in open orbit reconstruction to close dural defects or ethmoid defects when a pericranial flap is not available for closure. It is used for patients opting for an open cavity with prosthesis because it leaves sufficient space for the placement of the prosthesis and can help provide a vascularized bed for craniofacial implants.

Surgical Technique and Considerations

- ◆ The temporalis muscle is supplied by the anterior and posterior deep temporal arteries that originate from the internal maxillary artery system deep to the zygomatic arch. The TPFF is supplied by the superficial temporal artery.
- ◆ The temporalis flap can be accessed through the bicoronal approach for surgical resection. The muscle and its deep periosteum are elevated from a superior to inferior fashion, and the fascial attachments to the zygomatic arch are divided transversely to allow forward rotation of the muscle.
- ◆ The muscle flap can then be rotated into the orbit through a fenestration in the lateral orbital wall (lateral orbitotomy).
- ◆ The temporalis muscle fascia can be sutured to the region of the medial canthal ligament to prevent retraction.
- ◆ In comparison, the TPFF is able to rotate about its vascular pedicle with a good arc of rotation and is tunneled to reach the orbit.
- ◆ When the full extent of TPFF is harvested, the length of the flap will extend to the medial canthus and can be secured to the lacrimal crest, although there is a significant amount of soft tissue contraction with larger harvests that can result in late bone and hardware exposure.

Patient Selection and Perioperative Management

Patients wishing to have orbital restoration with a prosthesis may be good candidates for these regional flaps. The temporalis flap may create a concavity at the harvest site that is often aesthetically displeasing. The TPFF, on the other hand, may result in transient alopecia, or permanent alopecia and necrosis of the overlying skin in patients who have undergone radiation.

Option for Management: Radial Forearm Fasciocutaneous Flap

As described above, the fasciocutaneous radial forearm flap is useful in performing open orbital reconstruction in patients with orbital defects with an intact orbital rim. It is also particularly well suited for type I orbital defects when the patient opts for a closed reconstruction. The versatility and reliability of the RFFF has been well described in head and neck reconstruction and was discussed earlier in the chapter. In utilizing this donor site for orbital defects, it is important to ensure that there is adequate fat in the forearm for orbital volume restoration. A depressed orbital contour is considered a failure of closed orbital reconstruction; it is therefore important to ensure that the volume of well-vascularized fat is adequate for the size of the defect. An “ice-cream cone” orbital reconstruction has been used with good success and is a technique that rolls the proximal fat (but the most distal part from the vascular pedicle) in the external part of the roll, and the better vascularized more distal fat into the internal part of the wrap.⁴⁴ The roll or cone slides back into the orbit and is covered with the distal forearm skin, oriented in the coronal plane. This approach is being replaced by perforator-based free tissue such as the anterolateral thigh, rectus abdominis, and latissimus dorsi flaps.

Option for Management: Perforator Based Fasciocutaneous Flaps

Perforator-based free tissue, including the rectus abdominis, anterolateral thigh, and latissimus dorsi, can be used to perform closed orbital reconstruction when there is an intact bony orbital rim for type I defects. Each of these flaps has been described above, and the length of each pedicle can be designed, based on the perforators, to reach the necessary recipient vessels in the neck. The choice of donor site depends on the anticipated surface area and volume requirements, with a variable amount of muscle or fat or fascia harvested and inset.

These same flaps can also be used for type II and III defects, recognizing that a failure to reconstruct bony structures may affect facial contour and result in flap ptosis. When bone is not used for reconstruction, the loss of contour may be acceptable for type II defects but becomes less aesthetically pleasing for type III defects in which more than 30% of the bony orbital rim is missing. Although utilizing soft tissue without bone is faster, technically easier, and very reliable, it is aesthetically less pleasing. Our approach is to use vascularized bone to reconstruct the craniofacial skeleton unless there are mitigating factors such as significant comorbidities or a grave prognosis.

Option for Management: Radial Forearm Osseocutaneous Flap

The osseocutaneous radial forearm flap is a reliable option in patients with orbital exenteration defects involving 30% of the orbital rim (type II Defects), especially in radiated



Fig. 6.20 MRI (T1 with contrast) of a 39-year-old woman with a large right orbital leiomyosarcoma and history of retinoblastoma (RB)-1 mutation. She underwent excision via the Weber-Ferguson approach, right subtotal superstructure maxillectomy, orbital exenteration, anterior craniofacial approach, and skull base resection of intradural and extradural tumor via a bifrontal craniotomy.

patients who opt for a closed orbit. Optimizing orbital reconstruction requires consideration of the ultimate position of bone relative to the skin paddle in the final inset. This bone is well suited for use in orbital rim reconstruction and may be osteotomized once. This donor site is being replaced by the thoracodorsal scapular tip flap because the bone is easier to harvest, is easier to customize to the defect, transfers a higher volume of soft tissue, and has a longer vascular pedicle.

Surgical Technique and Considerations

- Because there is limited flexibility of the bone relative to the skin paddle, the defect site dictates the side of the donor site (**Fig. 6.20**).

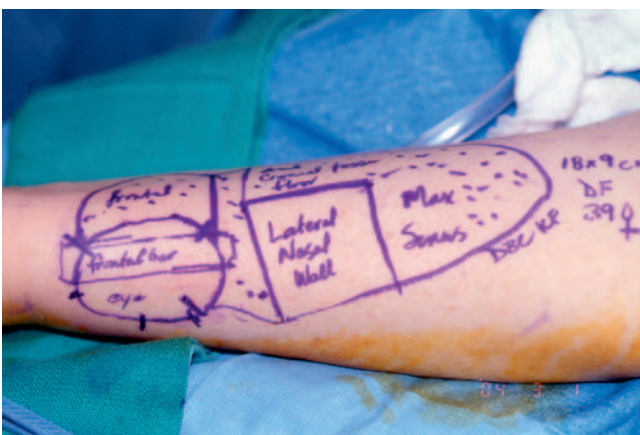


Fig. 6.21 Template of the osseocutaneous radial forearm free tissue harvest for a type II defect. The frontal bar was replaced to maintain projection, and the patient underwent closed orbital cavity reconstruction.

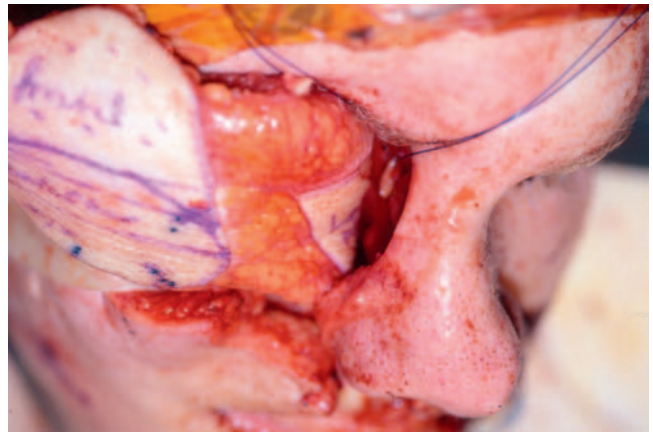


Fig. 6.22 Inset of the osseocutaneous radial forearm free flap. An additional skin paddle was utilized to reconstruct the lateral nasal wall and soft tissue used to obliterate the anterior cranial base floor and maxillary sinus dead space.

- When harvesting the flap, a wedge of bone is removed with beveled cuts and is centered on the attachment of the flexor retinaculum and the vascular supply from the radial artery, rather than cutting a tangent to the cross section (**Figs. 6.21** and **6.22**) of the radius. This allows for better control of the amount of bone harvested.
- Typically one should not harvest more than 40% of the circumference of the radial bone to avoid subsequent fracture (**Fig. 6.23**).



Fig. 6.23 Five months after orbitocranial reconstruction with an osseocutaneous radial forearm free tissue transplant. The patient refused refinement of the skin paddle and the medial canthal region. Note the symmetrical frontal brow, and stable appearance of the surrounding soft tissue and facial symmetry.

Patient Selection and Perioperative Management

The ideal patients for this flap are those with small bony defects requiring a limited bony reconstruction. Postoperatively, these patients must be carefully observed for the development of radius fracture.

Option for Management: Osseocutaneous Thoracodorsal Artery Scapular Tip (TDAST) Flap

The thoracodorsal artery scapular tip (TDAST) flap has become much more widely used in orbital reconstruction than the circumflex scapular artery flap. Reconstructive advantages of the TDAST for orbital reconstruction include a long pedicle and the ability to meet the three-dimensional requirements of the orbit. In addition, the scapular tip can be used without osteotomy for reconstruction of the orbital rim or malar eminence in the presence or absence of a globe. The main disadvantage of the scapular system of flaps is that a simultaneous two-team approach is not possible and may add to operative time.



Fig. 6.24 A 30-year-old woman who had a recurrent lacrimal gland adenoid cystic carcinoma following local excision and radiation, and underwent subcranial resection and orbital exenteration. Two years following her initial reconstruction, osseocutaneous radial forearm free tissue transfer she underwent revision surgery with excision of the flap skin paddle and reapproximation of her eyelids. This photo was taken 4½ years postoperatively. This closed orbital reconstruction draws attention to the normal eye.



Fig. 6.25 Thoracodorsal artery scapular tip (TDAST) template. The right lateral thorax is shown. The head is toward the left of the figure. The scapular tip used for frontal bone reconstruction is seen toward the middle of the figure, the latissimus skin was harvested to recontour the forehead skin and close the frontonasal fistula that had developed. Note the importance of the midaxillary line in surgical planning and localization of the anterior edge of the latissimus dorsi.

Surgical Technique and Considerations

- ◆ The thoracodorsal scapular tip flap is based on the angular branch of the thoracodorsal artery (**Fig. 6.24**).
- ◆ Unlike pedicle dissection for the scapular flap, the dissection for the vascular pedicle starts with identifying the thoracodorsal artery deep to the latissimus muscle usually by tracing back a branch to the serratus muscle. The angular artery can be traced as a branch of the thoracodorsal that vascularizes the distal tip of the scapula (**Fig. 6.25**).
- ◆ The muscular attachments are then released from the bony scapular tip using cautery. A reciprocating saw can be used to harvest the scapular tip bone while protecting the vascular pedicle (**Fig. 6.26**).

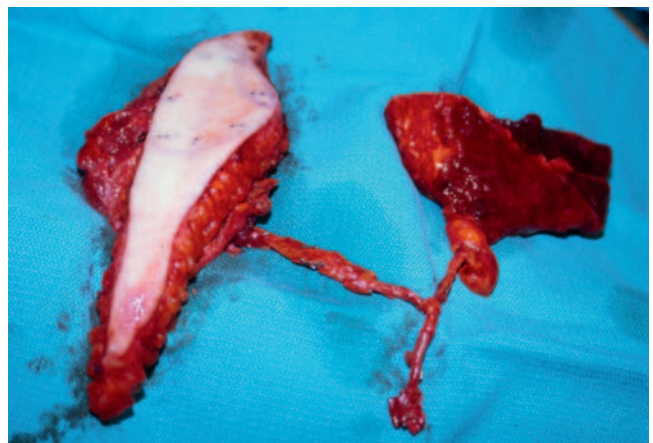


Fig. 6.26 The TDAST with the harvested latissimus myocutaneous paddle. The scapular tip is seen on the right side of the figure, and the latissimus paddle is seen on the left side of the figure. Note the length of the vascular pedicle and the mobility of the components of the reconstruction relative to one another.

- ◆ A long vascular pedicle can be achieved by tracing the thoracodorsal artery proximally to the subscapular artery (**Fig. 6.27**).

Patient Selection and Perioperative Management

This flap is well suited for type II or III orbital defects where orbital rim bone is required for adequate reconstruction. Care must be taken in selecting this flap in individuals who work extensively with their arms. Pain may be an issue when attempting to mobilize the arm. Physiotherapy may aid in achieving improved range of motion and return to function.

Option for Management: Osseocutaneous Scapular Free Flap

When orbital cranial defects involve more than 30% of the orbital rim, reconstruction with the osseocutaneous scapular free flap is indicated to restore the craniofacial contour. The subscapular system has consistent vascular anatomy, reliable size, and integrity that is usually unaffected by atherosclerotic disease. Its use has declined because the TDAST donor site has a much longer pedicle and better relative mobility between the soft tissue and the bone, and the three-dimensional anatomy of the scapular tip fits defects of the midface more easily. Occasionally, extensive defects involving the orbitocranial complex will also involve a dural defect. Management of this complex defect may benefit from

a combination of techniques including free tissue transfer and a pericranial flap.

Surgical Technique and Considerations

- ◆ In complex orbitocranial defects, the dural defect should be addressed first. The pericranial flap represents a reliable approach to separating the cranial and orbital subunits.
- ◆ Once the cranial and orbital cavities have been separated, the skin paddle of the flap can be designed to partition the nasal and cranial cavities. Suture can be secured to the surrounding bone to anchor the flap, as nasal and facial skin paddles are designed with an intervening area of de-epithelialized skin paddle.
- ◆ The nasal paddle is sutured into place followed by the external skin closure.

Patient Selection and Perioperative Management

Although several donor sites can be used for complex orbitocranial defects, sometimes a combination of local and free tissue transfer offers the most reliable approach. The pericranial flap used in combination with free tissue transfer is an excellent example of this technique.

◆ ORBITOMAXILLOCRANIAL DEFECTS

Orbitomaxillocranial defects that extend from the anterior cranial fossa to the maxilla usually involve the orbit, facial skin, and palate, and must be addressed to maintain adequate deglutition and speech (**Fig. 6.28**). Chapter 3 discusses the goals and principles when managing maxillary defects. For large orbitomaxillocranial defects, a decision must be made about whether to restore the upper and midfacial bony contour with vascularized or nonvascularized bone. In general, vascularized bone improves facial contour and can facilitate the future placement of craniofacial implants for facial and dental prostheses. Soft tissue reconstruction without bone is often more straightforward, involves less operative time, and is associated with fewer complications. These defects are extensive and have both large-volume and large-surface area requirements. The dura must be closed and supported by vascularized tissue, the volume of the orbit and midface must be restored, the skin must be resurfaced, and oronasal separation must be achieved (**Fig. 6.29**). If prosthetics are used, the cranial compartment requires separate closure, and retention of the prosthesis must be part of the reconstructive plan (**Figs. 6.30 and 6.31**).

Various classification systems for reconstructing maxillectomy defects have been described in the literature. Cordairo and Santamaria⁵⁰ and, more recently, Brown and Shaw⁵¹ proposed a classification and algorithm for midface reconstruction. Their systems for reconstruction are based on the surface area and volume of the defect and are helpful for extensive maxillectomy defects. However, this classification is not as useful for understanding an approach to cranial

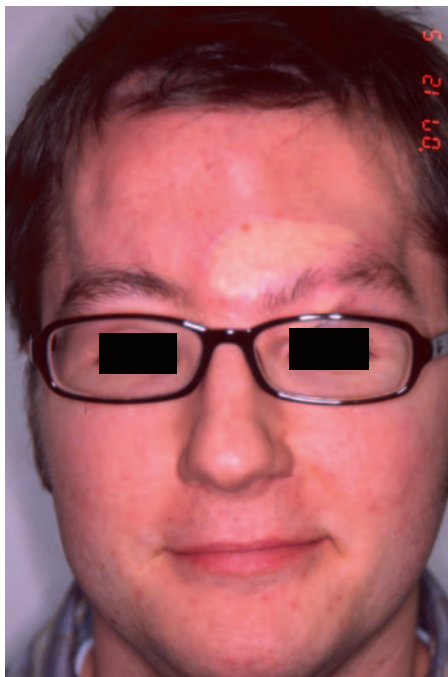


Fig. 6.27 A 19-month postoperative photo of the patient. Note that the projection of the frontal bone and the shape of the orbit have been restored. This young man was able to return to school as a full-time student.

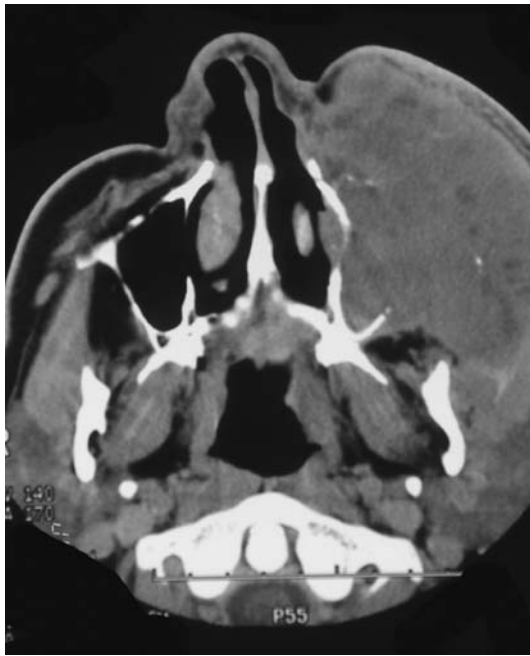


Fig. 6.28 An MRI of a 49-year-old man with massive squamous cell carcinoma arising from an inverting papilloma in the left maxillary sinus.



Fig. 6.29 The patient underwent craniofacial resection of the anterior and middle cranial fossa, total maxillectomy, orbital exenteration with removal of the entire bony orbit, total parotidectomy, and excision of the overlying skin, which measured 10 cm × 14 cm. The muscles of mastication within the infratemporal fossa were also resected. The temporoparietal flap can be seen over the frontal lobe, and the facial nerve can be seen over the ramus of the mandible.



Fig. 6.30 The template of the osseocutaneous scapular circumflex artery free tissue harvest. The patient required an extensive skin paddle as well as bony support of the orbit. The scapular bone was used to reconstruct the zygoma and the lateral inferior and medial orbital rims. The fat extending from the distal portion of the flap was used to line the floor of the anterior cranial fossa and support the dural closure. The patient underwent closed orbital reconstruction. The maxillectomy of the secondary palate was reconstructed with a maxillary obturator.



Fig. 6.31 The patient required postradiation reexcision of a squamous cell carcinoma at the temple, and eventually developed plate exposure and necrosis of the calvarial bone grafts used to reconstruct the lateral orbit. He subsequently underwent radial forearm free tissue transfer to cover exposed plates and was converted to an open orbital cavity with a prosthesis. The scapula remained intact, the primary site remained controlled, and the patient died of distant metastasis 3 years postoperatively.

defects. Defining the individual elements of reconstruction, as the Mount Sinai group has previously done, may be a more systematic approach when confronted with extensive orbitomaxillocranial defects.¹⁰

Option for Management: Prosthesis

A prosthesis can be used for facial recontouring and for maxillary reconstruction. Prostheses can provide a less technically demanding, noninvasive method of achieving oronasal separation, establishing maxillary dentition, and reestablishing the aesthetic contour of the face. The soft tissue reconstruction also needs to address dural closure and coverage of exposed bone to facilitate the placement of the prosthesis. Use of a prosthesis is only possible when the wound is stable. If the cavity is not well epithelialized and is not dry, the prosthesis will be less effective. Retention of the prosthesis must be addressed. There are three ways to retain the prosthesis: glue, magnets between the maxillary prosthesis and the facial prosthesis, and bone-anchored craniofacial implants.

In the case of skull base orbitomaxillary defects with a large cranial component, free tissue transplantation could be used to seal off the cranial cavity in combination with both a large facial and a palatal prosthesis that are connected to one another by a series of magnets. Another alternative is to use vascularized bone and soft tissue to reconstruct the skull base, the orbit, and the cheek with a maxillary prosthesis to reconstruct the dental arch. In patients who have a maxillary arch defect that is involving the secondary palate (with the premaxilla intact), a prosthesis can be used in combination with the autogenous tissue transplant. Vascularized bone can be used to reconstruct the infraorbital rim to help support the loading forces of the maxillary obturator. Diet is comparable between patients who have an obturator of the secondary palate and those with an intact palate.⁵²

If craniofacial implants are used to retain the prosthesis, there needs to be viable bone in critical areas of retention. Osseointegrated implants have a variable expected success rate depending on anatomic location, with orbital implants having the shortest life span. The success rates are lower in irradiated patients, with the best reported outcome of 70% when all sites for craniofacial implants are evaluated.⁵³

Overall, the use of prostheses as the primary reconstructive approach for large orbitomaxillocranial defects is declining and is being replaced by autogenous free tissue transfer. Prostheses are still useful in combination with soft tissue and bony reconstruction and retain their greatest use (1) in maxillary reconstruction for a secondary palate reconstruction to restore the dental arch, (2) as an orbital reconstruction, and (3) for a total nasal reconstruction.

Option for Management: Fasciocutaneous or Musculocutaneous Free Flaps

The rectus abdominis musculocutaneous donor site has been the most widely utilized flap for skull base defects involving the orbitomaxillary complex because of the anatomic consistency and length of the pedicle, its large volume,

and the relative ease of harvest.⁵⁴ It can be used not only to provide dura protection and reinforcement but also to reconstruct the palate and nasal lining. The pedicle can be tunneled in the anterior aspect of the parapharyngeal space between the mandibular angle and oral mucosa to reach neck recipient vessels. The donor tissue may be inset so that the rectus muscle is positioned to rest against the cranial defect, whereas the skin island(s) can be designed for nasal lining, palate mucosa, and orbital skin loss when necessary.

If the external skin of the cheek is intact, the rectus abdominis can be harvested with a single skin island to close the palate, and this is a straightforward solution. If the flap is thin, a second skin island to restore the lateral nasal wall can be used to prevent a cavity behind the skin. A three-skin-island rectus abdominis template can be used to resurface an external cheek defect in addition to the palatal defect and nasal airway. A long pedicle may also be harvested, avoiding the need for vein grafting. Simultaneous extirpation and reconstruction can be performed with a two-team approach. A main disadvantage of reconstructions using only soft tissue without bony support is the expected loss of facial contour and eventual ptosis of the flap. It is difficult to overlook the aesthetic result of a reconstructive approach using only soft tissue. Nonvascularized bone should not be used to try to improve the aesthetic outcome in irradiated patients because of the risk of wound breakdown, plate exposure, and graft loss.

The ALT donor site has been replacing the rectus abdominis donor site as the site of choice to reconstruct soft tissue defects in complex orbitomaxillary defects involving the cranial base because of its abundance of vascularized fat and availability of muscle. Like the rectus, the anterolateral thigh has limitations with respect to establishing facial contour and can develop ptosis over time. A series by Amin et al⁵⁵ describes the use of the ALT donor site in extensive defects involving the anterior skull base, orbit, and maxilla. The authors admit that despite retaining the volume and shape of the flap, there was obvious deficiency in projection at the malar eminence over time. They report that the addition of free bone grafts may help to reestablish the facial contour, but in patients in whom radiotherapy is anticipated, it has been shown that this option poses increased risk for plate exposure, infection, and absorption, in contrast to vascularized bone.

Shestak et al⁵⁶ successfully used the latissimus dorsi donor site in patients to fill the orbital cavity, seal the palate, and reestablish the volume of soft tissue of the face and cheek. The flap was utilized because of its bulk, reliable anatomy, and ample pedicle length. The latissimus dorsi myocutaneous flap without bony support, however, poses the problem of soft tissue ptosis and inadequate projection of the facial contour. When used in combination with scapular tip bone, the latissimus dorsi is a more appealing reconstructive option for extensive orbitomaxillocranial defects.

Option for Management: Thoracodorsal Artery Scapular Tip

The use of the TDAST donor site for reconstruction of extensive orbitomaxillary cranial defects is our reconstruction of

choice. The soft tissue is adequate for the reconstruction of these large defects, as discussed earlier in this chapter. The scapular tip bone contour matches the contour of the malar eminence, and the inferior orbital rim facilitates reprojection of the midface and prevention of ptosis of the soft tissue component of this donor site. If bone is desired for the maxillary alveolus, the lateral edge of the scapula can be oriented in the location of the resected maxillary alveolus, and the thinner part of the scapular bone can be angled toward the malar eminence and resected orbital rim to help restore midface projection.⁵⁷ This donor site addresses the problem of flap ptosis, loss of facial contour, the need for vascularized bone in a radiated field, and provides a long vascular pedicle. The disadvantages include patient positioning, increased operative time, and technical complexity.

◆ LATERAL AND POSTERIOR SKULL BASE

Similar principles to anterior skull base defects apply to reconstructing lateral and posterior skull base defects. True lateral and posterior skull base defects with intracranial communication are now becoming exceedingly rare due to the morbidity of total temporal bone resections and the poor prognosis associated with disease extending intracranially in this region.

Reconstruction of defects of the lateral or posterior skull base is determined by the location and extent of resection. Sleeve resection for lesions of the external auditory canal may be reconstructed with skin grafts. Cutaneous lesions involving the pinna may lead to more substantial soft tissue defects. When combined with parotidectomy and/or neck dissection, as is often necessary, an extensive deformity may result. Significant skin and soft tissue defects of the lateral and posterior scalp and skull base with exposed bone or dura must each be addressed.

There are many options for the reconstruction of lateral temporal defects, each of which depends on the size and location of the defect. These options include split-thickness skin grafts, cervicofacial rotational flaps, regional pedicled flaps such as the temporoparietal fascial flaps, latissimus dorsi, and pectoralis major flaps. Autogenous tissue transplantation is particularly useful for more extensive defects.

Option for Management: Skin Grafts

Skin grafts can effectively restore the epithelial covering of a lateral defect but result in noticeable contour deformities. In order for grafts to take, there must be a vascularized recipient bed, be it healthy periosteum or coverage with adjacent tissue such as a temporoparietal flap. The temporalis muscle flap is infrequently used as a vascularized bed because of its limited arc of rotation and donor-site deformity. Negative wound pressure therapy may be helpful in securing a skin graft to a lateral defect. In patients with exposed facial nerve,

one should avoid direct placement of skin grafts over the top of the nerve without intervening tissue to avoid nerve injury.

Option for Management: Cervicofacial Rotational Flap

Although the cervicofacial rotation flap is a favorable method of reconstruction for superficial lateral skull base defects because it provides a good color match, it does not effectively recontour defects. Its reliability decreases when used to cover temporal bone defects, when the facial artery is divided, in radiated fields, and in smokers.

Option for Management: Pedicled Flaps

The latissimus dorsi flap is an optimal regional rotational flap for lateral temporal reconstruction. It is well vascularized and has sufficient pedicle length to reach this defect site. Because it is a musculocutaneous flap, it has a tendency to become ptotic, and is not useful for fine recontouring. Operative time is also increased because the patient has to be placed in a semi-decubitus position and one cannot typically use a two-team approach.

The trapezius flap evolved with the development of perforator-based donor-site elevations. When first described, this donor site included harvest of the trapezius muscle and sacrifice of the accessory nerve.⁵⁸ Now the donor site can be harvested on a perforator from the transverse cervical artery located over the superior aspect of the deltoid. It has an adequate arc of rotation and is well vascularized. The flap may be utilized in conjunction with a neck dissection if the pedicle can be preserved in an oncologically sound manner. The use of perforator-based transverse cervical flaps is relatively new, and its reliability will have to be further evaluated.

The pectoralis flap has previously been shown to be a reliable flap in head and neck reconstruction.⁵⁹ However, it has limitations in lateral skull base reconstruction because of its inadequate length in reaching defects that involve the parietal or occipital scalp.

Option for Management: The Rectus Abdominis Free Flap

A variety of donor sites can be used to resurface lateral temporal defects. These donor sites include the rectus abdominis, the latissimus dorsi, and more recently the anterolateral thigh.^{60,61} Each of these flaps has been described in detail in this chapter. The lateral arm flap is a good option for this area but is technically complicated due to its small pedicle size and length.⁶² For the lateral arm transplant, the occipital artery should be used as the recipient vessel as it crosses the internal jugular vein. This donor site has compartmentalized fat that is good for contour matching, and ample nerve for nerve grafting.⁶³ The rectus and the latissimus dorsi sites



Fig. 6.32 This patient has a history of external beam radiotherapy for a malignant skull base tumor. Salvage resection resulted in a failed regional flap reconstruction and a posterior cranial defect.



Fig. 6.33 The defect is exposed and the cranial bone edges defined and freshened to expose bleeding vital bone. Drill holes and nonresorbable suture are then established around the periphery of the bony defect.

should not be elevated as musculocutaneous flaps because of the likelihood of ptosis and lack of contour matching unless the muscle and fascia are required for dural defects or patients who have been treated with external beam radiotherapy. Perforator-based elevations such as the ALT and the rectus provide better contour matching than if they are elevated as a musculocutaneous flap. The rectus site does not offer a donor-site nerve, whereas both the ALT and lateral arm have donor nerves. The posterior antebrachial cutaneous nerve from the lateral arm site has distal branching patterns that make multiple neurotizations to the facial nerve possible. Additional nerve can be harvested from the nerve to the lateral arm and the lateral antebrachial cutaneous nerve. The patient's body habitus also helps dictate which of these donor sites is most favorable.

Surgical Technique and Considerations

- ◆ Posterior defects of the skull base with either exposed dura or a history of radiotherapy exposure are rather difficult to manage without vascularized muscle and fascia (**Fig. 6.32**). The fascia helps to provide a watertight seal, whereas the muscle aids in healing.
- ◆ The defect should be exposed and the cranial bone edges defined and freshened to expose bleeding vital bone (**Fig. 6.33**).
- ◆ If a duraplasty is required, it should be completed. Ideally, vascularized or fresh nonvascularized fascia should be used (**Fig. 6.34**).

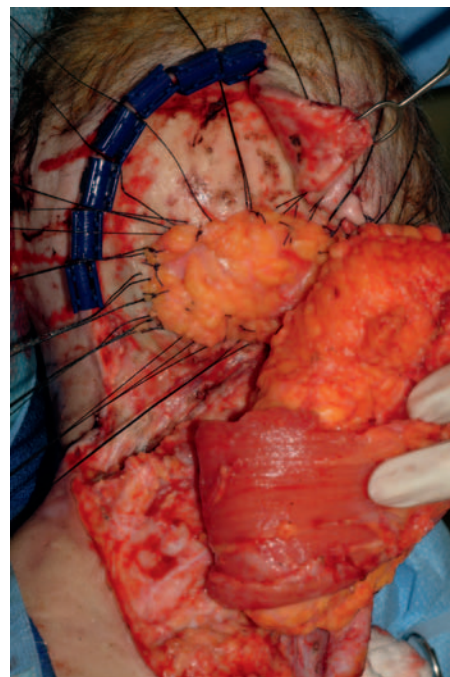


Fig. 6.34 The flap is composed of vascularized fat, fascia, and muscle. Skin can be used if necessary. The vascularized fat is used to obliterate the "dead space." The fascia and muscle are applied as a second and third layer, respectively.



Fig. 6.35 The vascularized muscle can be covered with a skin graft.

- ◆ Drill holes and nonresorbable suture can then be established around the periphery of the bony defect.
- ◆ The flap should be composed of vascularized fat, fascia, and muscle. Skin can be used if necessary. The vascularized fat is used to obliterate the “dead space.” The fascia and muscle should be applied as a second and third layer, respectively.
- ◆ The vascularized muscle can be covered with a skin graft (**Fig. 6.35**).



Fig. 6.36 Four months postoperatively, the defect is well healed.

- ◆ A lumbar drain should be placed to relieve cerebrospinal fluid pressure (**Fig. 6.36**).

Patient Selection and Perioperative Management

Although nonradiated patients tend to heal well, in complex wounds with dural defects, radiated tissue, or previously failed local flap reconstruction, vascularized tissue and, in particular, vascularized muscle can be exceptionally helpful. We use vascularized muscle to facilitate healing in most cases where the dura is exposed.

Postoperatively, a lumbar drain can be helpful to allow for the tissues to settle and seal to the surrounding native tissue bed.

◆ ADJUNCTIVE MATERIALS

Alloplasts are useful in anterior and lateral skull base reconstruction and are commonly utilized in combination with soft tissue to reconstruct contour deformities (**Fig. 6.17**). These materials have great value in skull base reconstruction but should be used only after careful consideration of placement, tissue quality, and microbial environment. Adhering to basic principles can be helpful for obtaining long-term stability of the implant. Implants are much more effective in patients who have not been radiated or have no plan for radiation.

Hydroxyapatite cement (HAC) is an alloplast that works as a scaffold for bone growth and is composed of interlinking calcium phosphate molecules. HAC is easy to sculpt, does not induce a foreign-body reaction or fibrous encapsulation, and remains isothermic when curing.⁶⁴ HAC can be used in conjunction with titanium mesh to reinforce the alloplast construct. Medpor implants (Porex Surgical, Inc., College Park, Georgia) are composed of porous high-density polyethylene and allow fibrovascular ingrowth. Low infection rates have also been reported with the use of this alloplast.⁶⁵ These implants may be prefabricated or molded intraoperatively. For larger implants, the thickness and the quality of the overlying tissue must be superior. Titanium mesh has also been used increasingly for structural support of larger areas.⁶⁶ This mesh has low bioreactivity, no donor-site morbidity, easy malleability, and is compatible with magnetic resonance imaging (MRI). Additional soft tissue is necessary in combination with titanium mesh to ensure a watertight seal of defects. For patients undergoing reconstruction after endoscopic skull base surgery, fibrin glue has also proven to be a valuable adjunct when constructing a watertight dural closure. It provides a quickly setting biologic adhesive to hold onlay grafts or fascial flaps to the underlying dural layer.

◆ CONCLUSION

Evolving reconstructive techniques are leading to improved functional outcomes in skull base surgery. Recognition of structures involved in defects using defect classification

schemes will aid the reconstructive surgeon in the design of the reconstruction. Identifying factors that may compromise a reconstruction such as perioperative radiotherapy is an important consideration when planning reconstruction of skull base defects. In these cases, preference should be given to vascularized free tissue.

The advent of perforator-based autogenous free tissue, including the rectus abdominis, anterolateral thigh, and latissimus dorsi flaps, has improved access to recipient vessels because of the ability to increase the pedicle length. These perforator-based soft tissue options can be customized to the defect.

The advance of transnasal expanded endoscopic approaches to skull base lesions has led to a shift from open craniofacial defects to endonasal defects. Increasing use of endoscopic approaches has been coupled with advances in endoscopic reconstruction, which are showing promise in their infancy.

Both open and endoscopic approaches to tumor ablation require a similar strategy for reconstructive decision making involving similar principles. A skull base defect should be approached based on the missing elements and be reconstructed accordingly. A useful scheme to characterizing anatomic defects was presented here. Sound reconstruction of defects will ensure more favorable functional and aesthetic outcomes.

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7

Scalp Reconstruction

Vivek V. Gurudutt and Eric M. Genden

Although seemingly straightforward, the reconstruction of the scalp has required creativity and innovation from surgeons throughout medical history. Creating a balance of appropriate coverage of underlying structures and maintaining cosmesis is oftentimes challenging. The range of defects can be of the scalp alone to deficits of the scalp, bone, and dura. Calvarial and scalp defects require managing potential cerebrospinal fluid leaks in addition to contouring the skull aesthetically.¹ Matching skin thickness and color as well as maintaining hair-bearing skin are goals of therapy that are not always attainable. Beyond trauma and congenital deformities, oncologic resection is a specific aspect of reconstruction that forces surgeons to be resourceful. Delays in treatment can lead to tumor progression and greater reconstructive complexity. Therefore, delaying resection to allow for tissue expansion is not often recommended.^{2,3} Scalp reconstruction should provide durable coverage, preserve blood supply, and allow proper wound drainage without breakdown and calvarial exposure.³ The challenge of patients with previous surgical scars, pre- and postsurgical radiation, and dural invasion requires much thought before treatment to fulfill these ideals.

The scalp can be a limiting factor in reconstruction. It is difficult to match in terms of thickness, color, and density of hair follicles. As a result, the best tissue type for scalp reconstruction is the scalp itself.¹ Management historically focused on primary closure and the use of skin grafts to cover areas of granulation. Preservation of the pericranium allowed for better take of grafted skin. As early as the 1600s, calvarial perforation was suggested as a method of promoting granulation formation. The development of local flaps allowed for closure of defects and preserving hair formation and skin thickness. In the late 1960s and early 1970s, Orticochea^{4,5} described a four-flap and eventually a three-flap technique for closing large scalp defects. These flaps enabled greater success at wound closure and preservation of hair-bearing tissue. For nononcologic reconstruction, the use of tissue expansion has allowed closure of large defects and maintaining some hair-bearing potential. Regional flaps were found

to be useful for reconstruction of occipital defects, but are limited in cosmesis. The challenges of reconstruction in the oncologic patient as well as a method of covering large surface areas of the skull were met with the development of microvascular reconstruction. Free tissue transfer has enabled surgeons to correct for previous surgeries, wound breakdown, and radiation therapy and still manage to cover entire scalp defects.

◆ RELEVANT ANATOMY

The scalp is composed of five distinct layers: skin, subcutaneous tissue, galea aponeurosis, loose areolar tissue, and the periosteum of the skull. The skin is the thickest compared with that on other areas of the body. The subcutaneous tissue contains most of the blood supply and lymphatics. The galeal layer is the strength layer and provides the most limitation of scalp movement. It attaches to the fascia overlying the frontalis muscle anteriorly, the temporoparietal fascia laterally, and the occipitalis muscle fascia posteriorly. Deep sutures at this level help alleviate tension along the skin.⁶ Epicranial muscles lie between the loose areolar tissue and the galea.⁷ Mobility is greatest at the parietal regions of the scalp where the temporoparietal fascia overlies the temporalis fascia.¹ Advancement from this area allows the most gain for rotational flaps. To help increase length, galeotomies can be used. Galeotomies at 1-cm intervals can decrease tension by 40% and gain 1.67 mm per incision.⁸ The cuts should be parallel to the blood supply to avoid devascularization, as the vessels are immediately superficial to the galea.^{6,9,10} Compromise of blood supply can lead to alopecia as well as necrosis of reconstructive flaps.¹⁰

The blood supply of the scalp is composed of branches of the internal and external carotid arteries. The anterior scalp receives its vascularization from the supraorbital and supratrochlear arteries. The superficial temporal artery and the posterior auricular artery supplies the scalp laterally and

posterolaterally, respectively. The superficial temporal artery supplies the greatest region in the scalp and branches into frontal and parietal vessels.⁷ The posterior aspects of the scalp receive its blood supply from the occipital artery above the nuchal line. Below this area is supplied by the perforators of the trapezius and splenius capitis muscles. Collateralization between these distinct territories is extensive. The use of local flaps should incorporate one of these major vessel systems to ensure adequate vascularization. Venous drainage from the frontalis, parietal, and occipital veins matches their corresponding arteries and drains the frontal, lateral, and posterior scalp into the external jugular vein.⁷

Neural innervation of the scalp is derived from a combination of cranial and cervical nerves. The anterior aspect is supplied by the first branch of the trigeminal nerve through the supraorbital and supratrochlear nerves. Laterally, the zygomaticotemporal, auriculotemporal, and the lesser occipital nerves provide innervation from the second and third branches of the fifth cranial nerve. Along the posterior scalp, cervical branches from C2 and C3 provide branches for the lesser and greater occipital nerves. Superiorly, the scalp is supplied by the third occipital nerve and is a branch of C3. In general, the pericranium of the vertex of the skull is less sensitive than the inferior areas. Neither the bones nor the veins of the skull receive any proprioception or nociception.⁷

◆ CLASSIFICATION OF DEFECTS

The size, depth, and location of the defect have the greatest impact as to what type of reconstruction should be used for scalp reconstruction. Although no one staging system exists, various algorithms have been suggested throughout the literature. Beasley et al¹¹ describe a staging system based on size and suggest potential reconstruction options. Scalp defects less than 200 cm² are classified as stage IA. Stage IB defects are the same size as stage IA, but they are associated with associated risk factors for failure, such as heavy trauma, infection, previous radiation, or a history of failed closure. Stage II defects are 200 to 600 cm² in size. Stage III defects are larger than 600 cm². Primary closure or local flaps are recommended only for stage IA defects, whereas free flaps are recommended for all other stages.¹¹ Leedy et al¹ differentiate defects by size and location. Anterior defects that are small and do not affect the hairline can be closed primarily. Rotational flaps are recommended to preserve or restore the hairline. Moderate (up to 25 cm²) and large defects (>25 cm²) can be closed with rotational advancement flaps and temporoparietal flaps, respectively. Tissue expansion and Orticochea flaps are also useful. For larger parietal defects, tissue expansion is required. Skin grafting over muscle and rotational flaps are other viable options. For large occipital lesions, Orticochea flaps and tissue expansion are useful as well as rotational flaps for smaller lesions that cannot be closed primarily. For vertex lesions, Leedy et al recommend primary closure for small lesions. For lesions less than 4 cm in width, closure with galeal scoring or a pinwheel flap is suggested. Otherwise, large rotational or advancement flaps

with back grafting or tissue expansion are needed. Leedy et al recommend free tissue transfer for patients with near-total scalp defects. Iblher et al² reviewed defects from oncologic resections and created an algorithm for closure based on size and location as well. For defects less than 3 to 4 cm in size, primary closure is recommended. If the defect is less than 6 to 8 cm (4 to 5 cm near the hairline), a split-thickness skin graft or local flap is advocated. Defects less than 8 to 10 cm necessitate free flap closure. If the larger defect is occipital, regional flaps are potential candidates for reconstruction. Although opinions vary on when to use which reconstructive option, a thorough understanding of each is necessary before tailoring a treatment plan for an individual patient.

◆ OPTIONS FOR RECONSTRUCTION

If primary closure cannot be achieved, even with the aid of galeotomies, several options are available to aid in reconstruction. Healing by secondary intention and allowing granulation of a defect is one method of closure. This technique requires meticulous care of the defect over several weeks of healing. However, it requires no additional surgery, does not require a vascular pedicle, and allows easy detection of tumor recurrence.¹² This technique is useful in patients with multiple medical comorbidities that may impede wound healing. Split- or full-thickness skin grafting can be used over the granulation bed.

Skin grafting over the defect is another method of closure. It is helpful to graft over areas of granulation, intact pericranium, or muscle to allow for the greatest chance for the graft to take. Burring down the outer layers of the calvaria and revealing the diploic space can be useful to help with vascularization if the pericranium is not viable.³ The ideal area to graft are nonirradiated defects with a good vascular bed and no need for postoperative radiation.³ Split-thickness skin grafts can cover a large wound area and allow for easy detection of tumor recurrence.^{11,12} Thinner grafts have a better chance of survival due to less nutritional requirements; however, they are not as durable as other modalities of closure. To improve graft survival on previously radiated bone that granulates slowly, galeal flaps can be used. These flaps rotate or transpose galea from sites adjacent to the defect and improve skin graft take by providing a vascular bed.¹³ Split grafts often are not cosmetically advantageous, with poor color and poor thickness matching. If meshing of the graft can be avoided, the appearance can be improved, but will sacrifice coverage surface area.

Tissue expanders follow the tenet of replacing scalp with scalp and are useful in patients not limited by time constraints for reconstruction. As a result, the oncologic patient is not the best candidate for the weeks necessary to allow adequate expansion time.^{2,3} The process involves implanting an expander and inflating the device over several weeks. A fibrous capsule forms around the expander, allowing an increase in blood supply to the scalp.⁶ The expanders must be 2 to 2.5 times the size of the defect to be reconstructed.¹⁴ The shape of the expander can affect the amount of tissue gained. Round, crescentic, and rectangular expanders allow

for 25%, 32%, and 38% tissue gain, respectively.¹⁵ Expanders are considered for planning of reconstruction or large defects of up to 50% of the scalp.¹⁶ The use of expanders enables maintaining the normal hair pattern by expanding the hair-bearing scalp. It is useful in tissue in which local flaps are inadequate secondary to the size of the defect, the trauma to tissue, or unacceptable alopecia or hairline distortion.¹ Although the area of skin is increased with expansion, the number of hair follicles remains the same. As a result, the density of follicles is decreased the more the scalp is expanded.⁶ Complications rates can be higher than 20% and are more likely to occur in infected or radiated tissue.^{3,11,17,18} Intraoperative rapid expansion allows a small increase in tissue gain by taking advantage of the mechanical creep of the tissue and with galeotomies may allow primary closure of larger defects of up to 5 cm at the vertex.^{10,14} External tissue expansion utilizes negative pressure on the scalp surface to increase the surface area for closure. External expander thickness ranges from 2 to 5 cm. The process takes 3 to 6 weeks and is associated with minimal risks.¹⁹

Local flaps transpose, advance, or rotate viable surrounding scalp into the defect for closure. They consist of skin, subcutaneous tissue, and galea. They enable closure of defects that cannot be managed with primary closure and provide excellent cosmesis. Combining the technique with skin grafting the donor sites allows for better coverage in more cosmetic areas. Relocating hair-bearing skin to more visible areas increases the overall aesthetic appeal of this technique. Attempts at preserving the natural orientation of the hair follicles also should be made. Local flaps are useful in defects less than 6 to 8 cm in size away from the hairline and up to 4 to 5 cm near the hair border.² The art of local tissue transfer requires experience and ingenuity for the surgeon to achieve acceptable closure and aesthetics. Various types of flaps can be utilized for closure of scalp defects and include yin-yang, pinwheel, Orticochea, V to Y, rhombic, Juri, and H flaps (**Figs. 7.1** and **7.2**).^{1,2,4-6,20}

Defects of the forehead and scalp are best managed as separate anatomic units to better preserve the hairline.⁶ If possible, local flaps should utilize a major arterial vessel to maintain axial blood supply.⁶ Minimizing tension at the skin with galeal sutures reduces the risk of alopecia along the suture line. Avoiding devascularization and tension of rotational flaps is paramount to avoiding wound breakdown. Skin staples are also helpful to avoid ischemia to hair follicles and can decrease incisional alopecia.¹ Dog ears that are formed during closure can be left to resolve over time and eliminate the risk of compromising blood supply during removal.^{1,6} The use of local flaps for large defects is limited due to the size of the flap necessary for closure as well as the inelasticity and lack of mobility of the scalp.²¹

Regional flaps for scalp reconstruction are useful for lower occipital or temporal defects. The reach of these flaps are the major limiting factor. Regional flaps are useful in palliative situations or in patients in whom longer procedures would be detrimental to the patient.² Temporoparietal, trapezius, latissimus dorsi, and pectoralis major pedicled flaps are potentially useful and provide coverage of 8 to 10 cm.² The aesthetic match of thickness and color is not ideal, and hair coverage is often inadequate; however, when the



Fig. 7.1 Medium-sized scalp defect with planned pinwheel closure.

temporoparietal flap is used with a skin graft, the result can be acceptable. In this approach, the temporoparietal flap is raised and transferred into the defect (**Fig. 7.3**). The skin graft can then be harvested and applied to the defect over the temporoparietal flap (**Fig. 7.4**). The long-term results demonstrate that the skin graft provides excellent color match and tone (**Fig. 7.5**).



Fig. 7.2 Wide undermining of the scalp allows for a pinwheel closure of the defect.



Fig. 7.3 An extensive defect of the lateral scalp and forehead managed with a temporoparietal flap transferred into the defect.

Free tissue transfer has enabled the reconstruction of the most complex defects. Near-total scalp defects, a history of prior radiation, scarring from previous surgeries, and failure of previous closure are difficult clinical dilemmas best closed with free flap coverage.^{1,10,20} Hussussian and Reece²¹ noted 90% of delayed free flap reconstruction was secondary to radiation therapy. The use of bone with free flaps can aid in



Fig. 7.4 The skin graft is placed over the vascularized temporoparietal flap.



Fig. 7.5 Three-month follow-up demonstrates a healed defect with an acceptable color match.

closure of calvarial defects, and watertight closure of the skin paddle allows closure of dural defects when positioned appropriately.¹⁰ Free tissue transfer can be limited in cosmesis secondary to thickness and color matching difficulty as well as the lack of hair-bearing skin. The superficial temporal as well as the occipital vessels can be used for anastomosis.^{1,11,21} If these vessels are not amenable, vessels in the neck are then explored. The length of the pedicle can pose issues for reconstruction and interposed vein grafts can be helpful in this situation.^{11,21} The latissimus dorsi flap allows a large size, low donor-site morbidity, and ease of harvest.²² The muscle has minimal bulk and a long pedicle, and can be used with or without skin.^{2,3,10} Adding the serratus anterior muscle allows for even greater scalp coverage.¹ The largest scalp defects can be covered with two latissimus dorsi free flaps. Rectus muscle flaps also allow large areas to be covered with limited thickness. Adding a skin graft to latissimus or rectus muscle eliminates a contour issue; however, flap monitoring, color matching/cosmesis, and durability of the skin is decreased.²³ The radial forearm is useful for smaller defects, and the anterior lateral thigh is another potential source in patients with limited flap bulk. Serratus anterior muscle and omentum can be used with skin grafts to gain coverage.²⁴ The serratus flap can be harvested with vascularized rib to address calvarial defects.^{21,25} Parascapular fasciocutaneous flaps can be considered for reconstruction and offer a good thickness match to the scalp.²³ Scapular flaps with skin offer a good substitute for forehead skin in terms of color, texture, and thickness. The length of surgery and recovery in older patients with multiple medical comorbidities can be a limiting factor in free flap reconstruction.²³ Balancing patient body habitus, medical conditions, as well as the nature of the defect is necessary in determining the type of flap to be used.



Fig. 7.6 Clinical case of a patient with prior radiotherapy and an infected cranioplasty. The cranioplasty material was removed and the defect washed out.

Techniques such as hair transplantation can be used to improve aesthetics in patients after reconstruction. The results are the most successful if done as a second procedure and if follicular unit grafting is used.^{1,6} Success rates for hair implantation in free flaps are 90% and can be incorporated into split-thickness skin grafts that overlie myofascial flaps.¹⁰

Calvarial defects add to the complexity of a scalp wound. Cranioplasty with the use of titanium mesh provides a solid, malleable, fixable framework, and can be used with methyl methacrylate; however, it can be subject to infection and extrusion^{9,21,23} (**Fig. 7.6**). Tissues with radionecrosis or infection are more likely to have complications with alloplastic materials, and may benefit from autologous tissue.²¹ Infected bone should be removed and cranioplasty delayed²⁶ (**Fig. 7.7**). Autologous split calvarial defects, split rib, and vascularized rib grafts are all potential reconstructive options. Chang et al²⁷ recommend inclusion of myocutaneous free

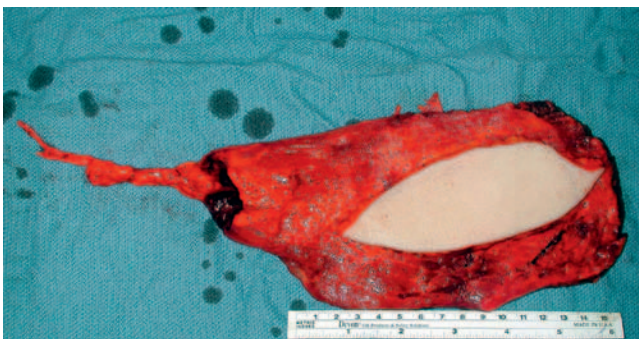


Fig. 7.7 A latissimus dorsi flap is elevated with a skin paddle. The long vascular pedicle and the vascularized muscle provide an excellent bed for healing.



Fig. 7.8 The flap is used to reconstruct the defect, and the vascular anastomosis is performed with the facial vessels.

tissue for dural and calvarial defects to eliminate intractable dead space of the wound, decrease osteomyelitis risk, and aid in sealing off the surrounding tissue margin. Morbidity from cranioplasty is related to residual devascularized or infected bone in the wound, inadequate coverage with vascularized tissue, and the type of material used²³ (**Figs. 7.8** and **7.9**).

Artificial dermal grafts are another method of helping scalp healing. The outer layer is composed of silicon and provides mechanical protection and moisture modulations. The inner layer is a collagen-glycosaminoglycan matrix that provides a template for cellular growth.²⁸ The artificial dermis is placed and the silicone layer is removed after 3 to



Fig. 7.9 Six-month follow-up demonstrates the well-healed wound.

6 weeks, and a split-thickness skin graft can be placed. This process reduces operative time, donor-site morbidity, and hospital stay, as compared with flap reconstructions, and increases cosmesis and skin graft take with the regenerated tissue.²⁸ However, a second surgical procedure is required and may not be as successful in patients needing or having completed radiation therapy.²⁸

The reconstructive surgeon must be aware of potential pitfalls in scalp surgery. Patients who have undergone multiple resections and reconstructions have less tissue pliability and compromised vascularity of the scalp.² Newman et al³ noted complications to be significantly higher in anterior scalp repair compared with other subsites. Thinner skin anteriorly provides less protection to bone or alloplastic materials and may contribute to this phenomenon. Contamination from the frontal sinus may also play a role in failure.³ Postoperative complications are more often encountered in patients with cerebrospinal fluid leaks and in those undergoing adjuvant chemotherapy or radiation.³ Radiation to the scalp induces fibrosis and reduces elasticity. It is imperative to limit tension on the wound and preserve vascularity to decrease breakdown risk.¹ The use of vascularized tissue is essential to provide durable and reliable results.

◆ CONCLUSION

Scalp reconstruction can be achieved using a variety of options ranging from a skin graft to a regional flap to free tissue transfer. Determining the optimal approach to reconstruction is predicated on the defect size and the patient's history of prior radiotherapy. A careful preoperative history and a discussion with the patient related to goals and expectations can help guide the surgical options. Extensive defects of the scalp continue to represent a challenge; however, free tissue transfer provides a dependable option.

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8

Management of the Paralyzed Face

Eric M. Genden

Facial paralysis may result from a variety of etiologies, including trauma, viral infection, neoplastic disease, and idiopathic causes. Although the approach to management of the paralyzed face is often predicated on the etiology of the paralysis and the expectations for recovery, this chapter focuses on the techniques commonly used for facial reanimation.

Arguably, there are few deficits that impact a person's self-image more than facial paralysis. The combination of aesthetic and functional impairments that result from a facial paralysis can be psychologically devastating, leading to depression and social isolation. In addition to the obvious aesthetic impact of a facial paralysis, the functional impairment can be significant. Incomplete eye closure can result in visual impairment, midface atony can result in impaired nasal breathing, and laxity of the lower face can result in deficits in speech and oral competence. Rehabilitation of the facial paralysis may be achieved through nerve regeneration, static reconstruction, or dynamic reconstruction. Determining the optimal approach for facial rehabilitation depends on the expectations for facial nerve regeneration and the goals and expectations of the patient.

◆ ASSESSMENT OF THE PATIENT WITH FACIAL PARALYSIS

Patient Examination

A careful patient assessment is important to determine the appropriate management of a patient with facial paralysis. Understanding the etiology of the injury is essential. This includes an understanding of the likelihood of nerve recovery. Once the degree of injury and the expectations for recovery have been determined, a detailed examination should be performed. The examination should assess the motion of

the upper, middle, and lower thirds of the face independently. Beginning with the upper face, visual acuity, corneal integrity, eyelid closure, tearing, Bell's phenomenon, lagophthalmos, lower lid tone, and brow position should be evaluated. The middle third entails a nasal examination, with a detailed evaluation of the nasolabial fold, nasal alar position, and the nasal airway. The lower third examination should assess the general tone of the lower third of the face with specific emphasis on oral competence, position of the lower lip, and the degree of depressor muscle dysfunction.

In addition to the general assessment of facial dysfunction, the lower third evaluation requires a careful assessment of the smile pattern. Smile patterns were initially classified by Rubin¹ in 1974 into three types. Type I is the most common smile pattern, occurring in almost two thirds of patients, and it is dominated by action of the zygomaticus major muscle. Type I smiles are characterized by the mouth moving laterally and superiorly, with subtle elevation of the upper lip. Type II, the canine smile, occurs in one third of patients and is dominated by levator labii superioris action, appearing as vertical elevation of the upper lip, followed by lateral elevation of the corner of the mouth. Type III occurs in a minority of patients and is the full denture smile, or "toothy smile," produced by simultaneous contraction of the elevators and depressors of the lips and angles of the mouth. Noting the smile type is important because suspension techniques can be modified to accommodate the smile type.

Assessment of the Nerve Function

Before deciding on the approach to facial reanimation, several crucial factors should be defined. These include the timing of the injury, the degree of the injury, and the condition of the proximal and distal facial nerve.

Electromyography (EMG) is recommended for all patients whose injuries occurred more than 12 months before

Table 8.1 Electromyography Guide

Normal voluntary action potentials indicate the presence of functioning motor axons with stimulating motor units of facial muscle.

Polyphasic potentials indicate reinnervation and may precede clinical reinnervation.

Denervation or fibrillation potentials indicate that denervated muscle exists.

Electrical silence, with no potentials seen, indicates muscle atrophy.

presentation (**Table 8.1**). EMG demonstrates polyphasic or normal voluntary action potentials in those with active reinnervation. In these patients the presence of polyphasic potentials may mean that reinnervation is occurring and facial movement may return. Although temporizing surgical procedures may be warranted, reanimation surgery should not be performed. When the EMG demonstrates fibrillation or denervation potentials, the muscle is denervated, and in this situation cable nerve grafting is an option for management. In long-standing paralysis (more than 18 months), severe atrophy of the facial muscles occurs, limiting reinnervation techniques. EMG is helpful in determining the degree of facial muscle atrophy. When muscle atrophy has occurred, the EMG may demonstrate “electrical silence,” consistent with complete denervation atrophy of the facial muscles. In these cases, nerve grafting or nerve transfer is not indicated, and muscle transfers may be considered.

◆ RELEVANT ANATOMY

The extratemporal facial nerve has five divisions: the temporal, zygomatic, buccal, mandibular, and cervical. Each division innervates a group of muscles.

Understanding the general nerve muscle distribution of the 18 paired muscles of the face is important in determining the impact of a facial paralysis and the optimal reconstructive technique to address the deficit. An understanding of these relationships is helpful, but facial expression is highly individualized. No two smiles are the same, and although the muscles of action may be similar between two people during a smile, the angles and vectors of muscle contraction result in a unique smile pattern. Replicating the smile pattern in the paralyzed face is a challenge that continues to elude us in spite of our rather complex reconstructive techniques.

◆ CLASSIFICATION AND GRADING OF FACIAL PARALYSIS

A variety of facial nerve grading scales have been described, but the House-Brackmann scale has been adopted by the Facial Nerve Disorders Committee of the American Academy of Otolaryngology–Head and Neck Surgery in 1985 because of its reproducibility and ease of use (**Table 8.2**).² The House-Brackmann scale is useful for evaluation of general function,

but it is insufficient for precise assessment of defects affecting one or more branches of the facial nerve.

◆ MANAGEMENT OF THE ACUTE INJURY

When the facial nerve is acutely transected, an immediate neurotomy will yield the best results for reinnervation. Acute injury may occur during a surgical resection or traumatic injury. If it occurred less than 72 hours earlier, the injury can still respond to electrical stimulation for nerve identification; however, after 72 hours, the distal nerve does not stimulate and the surgeon must rely on surgical dissection and visual identification of the distal nerve branches.

Option for Management: Primary Reanastomosis

Primary reanastomosis in the acute setting offers the best opportunity for recovery. In our experience, an immediate

Table 8.2 The House-Brackmann Grading System

Grade	Description	Characteristics
I	Normal	Normal facial function in all areas
II	Slight	Appearance: slight weakness noticeable on close inspection; may have very slight synkinesis At rest: normal symmetry and tone Forehead motion: moderate to good function Eyelid closure: complete with minimal effort Mouth motion: slight asymmetry
III	Moderate	Appearance: obvious but not disfiguring weakness between the two sides; noticeable but not severe synkinesis, contracture, or hemifacial spasm At rest: normal symmetry and tone Forehead motion: slight to moderate movement Eyelid closure: complete with effort Mouth motion: slightly weak with maximal effort
IV	Moderately severe	Appearance: obvious weakness or disfiguring asymmetry At rest: normal symmetry and tone Forehead motion: none Eyelid closure: incomplete Mouth motion: asymmetric with maximal effort
V	Severe	Appearance: only barely perceptible motion At rest: asymmetric Forehead motion: none Eyelid closure: incomplete Mouth motion: slight movement
VI	Total	No facial function

Source: From House JW, Brackmann DE. Facial nerve grading system. Otolaryngol Head Neck Surg 1985;93:146. Reprinted by permission.

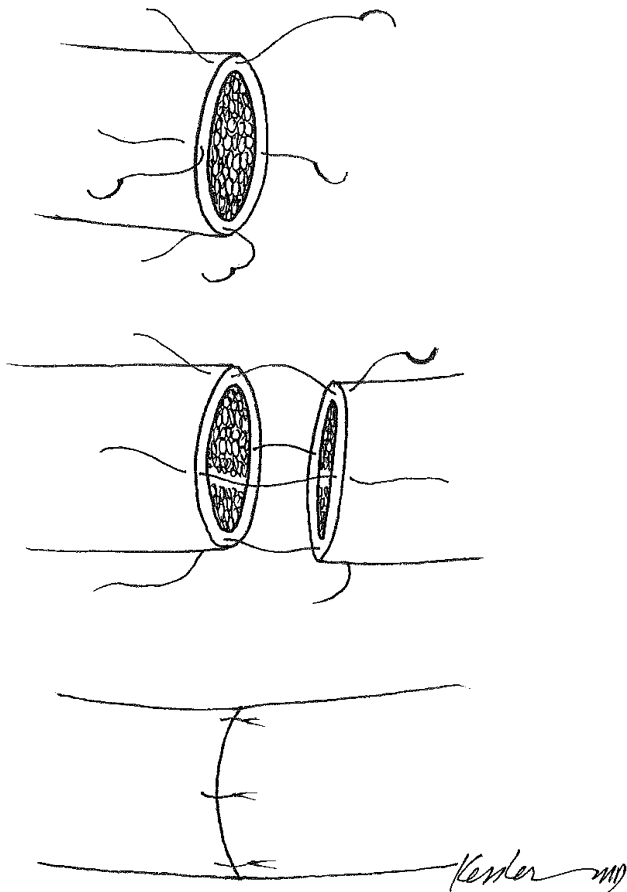


Fig. 8.1 The surgical technique for primary neurorrhaphy requires epineural sutures placed meticulously to achieve a tension-free neural anastomosis. The endoneurium should be trimmed, and four to six microsutures should be placed in an interrupted fashion.

repair that is performed with meticulous surgical technique can provide excellent results. In general, distally occurring injuries result in better outcomes than proximally occurring injuries. It is clear that the best results are achieved when there is a tension-free anastomosis.

Surgical Technique and Considerations (Fig. 8.1)

- ◆ When a nerve transection has occurred, whether incidental or intentional, it is important to examine the proximal and distal nerve for crush injury. The nerve should be trimmed back to achieve an area of clean transection without epineural or perineural crush injury.
- ◆ When the proximal and distal ends of the nerve are opposed, there should be enough nerve length that there will be no tension on the neural anastomosis. If there is tension, a cable graft should be performed.
- ◆ Under high-powered magnification, an 8.0, 9.0, or 10.0 microsurgical suture should be used to perform an epineural neural anastomosis. We recommend using the fewest number of sutures to achieve the anastomosis.

Four to six epineural sutures typically achieve the desired result. There should be no attempt to realign individual fascicles.

- ◆ It is ideal that the neural anastomosis be performed in a well-vascularized bed. A bed that has been previously radiated or laden with scar will inhibit healing. In some cases, transposition of healthy vascularized tissue, including muscle or temporoparietal fascia, may help the process of healing.

Patient Selection and Perioperative Management

Primary neural reanastomosis is best performed in the setting of an acute nerve transection when there is no tension on the anastomosis. This approach can be used in cases where the primary injury has occurred up to 1 year earlier; however, the best results are always achieved in those who are treated early in the time course. Results are also best in young patients. A poorly vascularized tissue bed is often a deterrent to healing. Any effort to improve the vascularity of the tissue bed will aid healing.

Postoperative nerve regeneration occurs at a millimeter per day in the optimal scenario. The age of the patient, the health of the patient, and the nature of the tissue bed will all play a role in the speed of recovery.

Option for Management: Nerve Graft

A cable or an interposition nerve graft is commonly used following a radical parotidectomy with facial nerve sacrifice, a temporal bone resection, or traumatic avulsion. As discussed, a tension-free repair is critical, and when a tension-free apposition cannot be achieved using primary nerve ends, cable grafts are recommended. A nerve graft can be harvested from the greater auricular nerve, the sural nerve, the cervical nerve, or the medial antebrachial cutaneous nerve. Although the greater auricular provides a unifascicular nerve with very good diameter, the sural and antebrachial cutaneous nerves offer nerve grafts that branch and can be used when multiple nerve grafts are required (**Fig. 8.2**). The

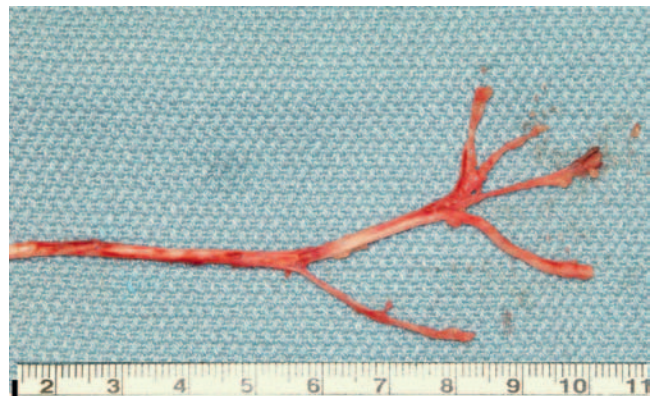


Fig. 8.2 The sural nerve and antebrachial cutaneous nerves offer branching that is ideal for multiple neurorrhaphies. Shown is a sural nerve graft demonstrating the graft length and branching pattern.

sural nerve is the longest donor nerve, with up to 70 cm of graft available.

Surgical Technique and Considerations

- ◆ The donor site is located distant from the surgical resection, allowing a second team to simultaneously harvest nerve tissue.
- ◆ The sural nerve is formed by the junction of the medial sural cutaneous nerve and the peroneal communicating branch of the lateral sural cutaneous nerve between the two heads of the gastrocnemius muscle. The nerve lies immediately deep to and behind the lesser saphenous vein, with multiple nerve branches arising near the lateral malleolus.
- ◆ A pneumatic tourniquet can be used to preserve hemostasis.
- ◆ A transverse incision is made immediately behind the lateral malleolus. “Stair-step” horizontal incisions along the course of the nerve provide appropriate exposure during the harvesting procedure.
- ◆ The neurorrhaphy can be performed with interrupted sutures using 9.0 or 10.0 monofilament nylon.
- ◆ Both ends of the nerve graft and the proximal and distal stumps should be transected cleanly. Three to six simple epineural sutures should be used to achieve the anastomosis.

Patient Selection and Perioperative Management

This technique is used when a tension-free apposition cannot be achieved using primary nerve ends. If grafting is not undertaken at the time of nerve sacrifice, it should be completed within 72 hours, so that the facial nerve stimulator can be used to identify the distal branches. In those cases where the primary repair is not performed at the time of injury, the nerve ends should be tagged for identification at a later time, because the distal branch will not stimulate after 72 hours and it is more difficult to locate and identify. Donor-site morbidity for each of the donor sites is low; however, caution should be taken with diabetic patients and those with peripheral vascular disease. In these patients ischemic pressure necrosis could occur as a result of the sensory deficit along the lateral aspect of the foot.

◆ MANAGEMENT OF THE BROW AND UPPER EYE LID

Management of the upper division of the face is arguably the most important first step to management of a patient with facial paralysis. Protection of the eye is essential because patients with upper lid paralysis suffer from a loss of the blink reflex, leaving the eye vulnerable to injury and drying, which in turn can lead to corneal ulceration and, in severe

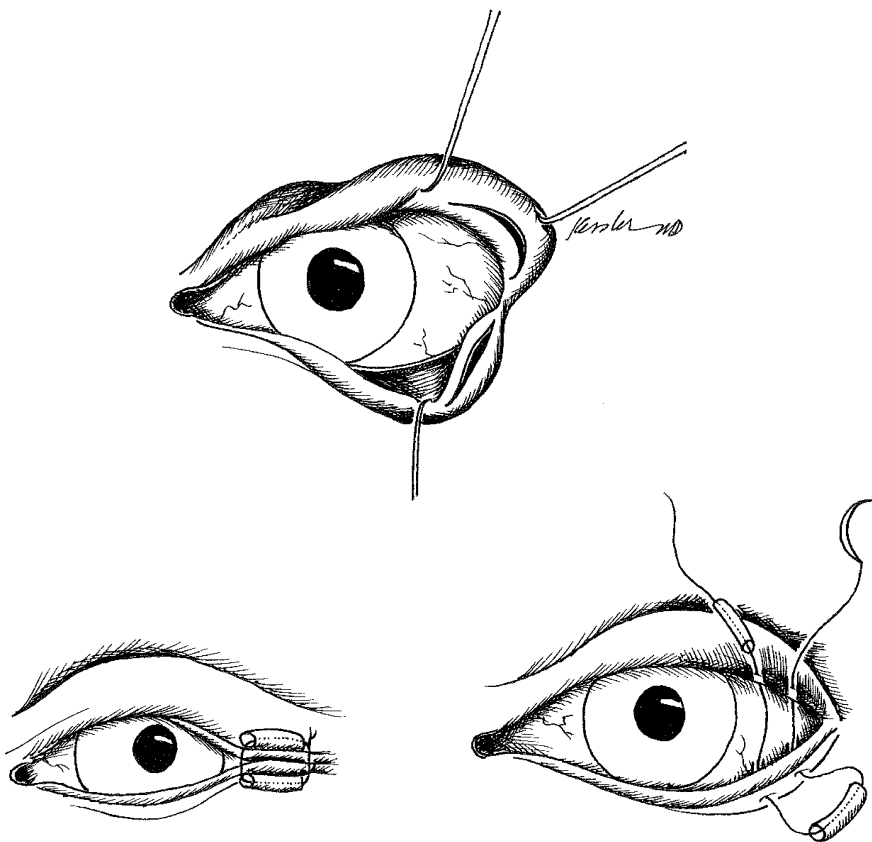


Fig. 8.3 The lateral tarsorrhaphy is a reversible procedure that can be performed in the office and often provides excellent protection.

cases, blindness. Where there is low corneal risk and a good prognosis for recovery, intensive lubricants and taping or padding is typically acceptable. However, when a conservative approach is inadequate, intervention may be indicated. Management of the upper lid, the lower lid, and, in some cases, the brow may be indicated.

Option for Management: Lateral Tarsorrhaphy (Fig. 8.3)

The lateral tarsorrhaphy offers a simple and reversible procedure for the paralyzed upper lid. It can be performed in the office and often provides excellent protection in the select patient.

Surgical Technique and Considerations (Fig. 8.4)

- ◆ This procedure can be performed in the office. Anesthesia can be administered with tetracaine ophthalmic drops and an injection of subcutaneous local anesthesia.
- ◆ The lateral tarsorrhaphy should be planned for a 5- to 10-mm margin of closure, depending on the anatomy of the patient and the position of the iris.
- ◆ We recommend a tongue-and-groove tarsorrhaphy where the upper lid margin acts as the tongue and is inserted into the groove of the gray-line incision.
- ◆ Nonabsorbable 4.0 suture is passed through bolster tubing and the lids are drawn together.

Patient Selection and Perioperative Management

In those cases where recovery is expected but the lubricants and taping are not adequate, medial or lateral tarsorrhaphy may be considered. The advantage of this technique is that it can be performed in the office and it is reversible.



Fig. 8.4 Clinical case. The tarsorrhaphy provides protection to the cornea but maintains a visual field that is limited on lateral gaze.

Postoperatively, continued lubrication and hydration should be continued and slowly tapered until it is determined that the tarsorrhaphy provides sufficient protection. Overcorrection may interfere with vision; however, undercorrection may not sufficiently protect the eye. This may not become apparent for several weeks after the initial surgery.

Option for Management: Gold Weight Implant

In those cases where a tarsorrhaphy is not adequate, the upper lid gold weight implant often provides an effective technique to close the upper lid and protect the eye.

Surgical Technique and Considerations (Fig. 8.5)

- ◆ The supratarsal fold is marked and the upper lid is injected with local anesthesia.
- ◆ An incision is made through the skin and anterior lamellar layers, and a pocket is created immediately superficial to the tarsal plate.
- ◆ The weight is placed in this pocket so that its inferior border is parallel to and just 2 mm above the eyelash line.
- ◆ The implant is secured with undyed suture.
- ◆ The orbicularis-levator complex is reapproximated with absorbable suture, and the skin is closed with a fast-absorbing chromic gut suture.

Patient Selection and Perioperative Management

Preoperatively, using adhesive, several gold weights should be used to identify the optimal weight for the patient. Ideally, the weight should facilitate closure of the lid but not cause a vision-obstructing lid lag. It should be remembered that the upper lid will fatigue throughout the day, so a weight



Fig. 8.5 Clinical case. The gold weight is inserted through an incision made in the supratarsal crease.

that is slightly heavy in the morning hours may result in an obstructing lag at the end of the day.

Postoperatively, lid closure should be assessed 2 weeks after surgery, and patients with a history of glaucoma should be monitored carefully.

◆ MANAGEMENT OF THE LOWER EYE LID

In the event of a facial paralysis, weakness of the lower lid can lead to ectropion, eversion of the lacrimal punctum, and pooling of tears. Lower lid laxity and its associated disorders may represent a significant problem for the patient with a facial paralysis. Evaluation of the lower lid is best achieved using the snap test and a careful evaluation of sclera show. Although medial lid laxity can be problematic, lateral ectropion is more common. For those patients with medial lower lid laxity, the punctum can be repositioned by performing a medial tarsorrhaphy with repositioning of the punctum. This can be performed via a conjunctival preauricular approach. For a variety of reasons, lateral lid laxity is more common and therefore requires an understanding of the options of management.

Option for Management: Lateral Canthopexy

Lateral laxity often causes sclera show, tearing, and sclera irritation. Management of lateral lid laxity can be achieved with a lateral canthotomy and inferior cantholysis under local anesthesia.

Surgical Technique and Considerations

- ◆ The patient is administered tetracaine eyedrops, and the anterior lamella skin fold and posterior lamella skin fold are injected with Xylocaine 1% with epinephrine 1 : 100,000 dilution. The lateral canthus and medial aspect of the lateral orbit are injected with local anesthetic.
- ◆ The anterior lamellar skin is separated from the posterior lamella skin, and the canthal tendon is exposed by removing the skin.
- ◆ The lateral canthal tendon is then trimmed to provide the appropriate tension against the globe.
- ◆ The tendon is then suspended to the periosteum of the medial aspect of the lateral orbit in a position 2 to 4 mm superior to (Whitnall's tubercle).

Patient Selection and Perioperative Management

The lateral canthopexy is indicated for patients with symptomatic moderate to severe lid laxity. This is documented with a pinch test and sclera show. This technique addresses medial laxity, but in cases of significant punctum eversion a medial canthopexy should be considered.

Postoperative management is centered around lubrication and evaluation of eye protection to determine if the lateral

canthopexy provides a satisfactory result or if adjunctive procedures are required.

◆ MANAGEMENT OF THE MIDDLE AND LOWER FACE: STATIC TECHNIQUES

Facial paralysis affects the midface by causing asymmetry and nasal obstruction. Nasal obstruction occurs because of collapse of the alar sidewall and loss of intrinsic dilator naris tone. The static sling procedure and or alar batten grafts have been used to manage this often bothersome problem. Similarly, rehabilitation of the lower face in the facial paralysis patient is an extremely important aspect of patient management. Generally, techniques to manage the lower face include reinnervation techniques, dynamic muscle transfers, and static techniques. Static techniques offer the advantage of immediate rehabilitation of the paralyzed face addressing problems such as drooling, poor articulation because of air escape, and oral incompetence. Static techniques can also be helpful to manage nasal collapse of the alar complex through resuspension techniques.

Although tensor fascia lata is most commonly used for static suspension, a variety of materials have been used, including acellular human dermis (AlloDerm) and polytetrafluoroethylene (PTFE) (e.g., Gore-Tex). These approaches have been developed to limit the donor-site morbidity; however, the risk of infection and the general attempt to limit the use of alloplastic materials have limited the popularity of these techniques.

Option for Management: Tensor Fascia Lata Suspension (Fig. 8.6)

Tensor fascia lata is a source of autologous tissue that is reliable and well tolerated for static suspension of the middle and lower face. Its shortcomings are limited to the donor-site pain and scar.



Fig. 8.6 Clinical case. The tensor fascial sling can be designed to place one to four strips of fascia to achieve the desired result. The fascial sling should be anchored to the periosteum of the zygoma.

Surgical Technique and Considerations

- ◆ The procedure is initiated by harvesting tensor fascia lata from the lateral thigh.
- ◆ Incisions in the preauricular or temporal area are performed first. This is followed by incisions in the nasolabial crease and vermilion border of the upper and lower lips adjacent to the commissure.
- ◆ A subcutaneous dissection is performed to create a tunnel connecting the temporal region to the oral commissure. The dissection is extended to the nasolabial fold.
- ◆ Tensor fascia lata is harvested via a stair-step incision and harvested with a tendon stripper.
- ◆ A single strip of tensor fascia lata is cut to appropriate size and can be split near the end to include slips for attachment to the upper and the lower lips.
- ◆ Nonabsorbable sutures are placed to secure the tensor fascia lata to the orbicularis oris muscle and deep dermis.
- ◆ Similar fixation is performed for a strip to the nasolabial fold and ala.
- ◆ The sling is then suspended and secured with permanent suture to the temporalis fascia or to the periosteum of the zygoma.
- ◆ Overcorrection of the smile is essential. The first or second molar should be exposed.

Patient Selection and Perioperative Management

Patients who are not candidates for dynamic reanimation are appropriate candidates for tensor fascia lata suspension.

◆ MANAGEMENT OF THE LOWER FACE: DYNAMIC MUSCLE TRANSFER TECHNIQUES

Management of lower face paralysis with dynamic muscle transfer has the potential to provide symmetry and movement of the lower face. The options include temporalis muscle transfer, masseter muscle transfer, and free muscle transfer. Free muscle transfers include the gracilis, the pectoralis minor, and a variety of other muscle transfer donor sites that have been described in the literature.

Option for Management: Temporalis Muscle Transfer (Fig. 8.7)

The temporalis muscle transfer offers an opportunity for semi-volitional facial movement that can be initiated with jaw clenching for patients with a facial paralysis. The technique has advantages and disadvantages; however, with experience, this technique can provide excellent results. The

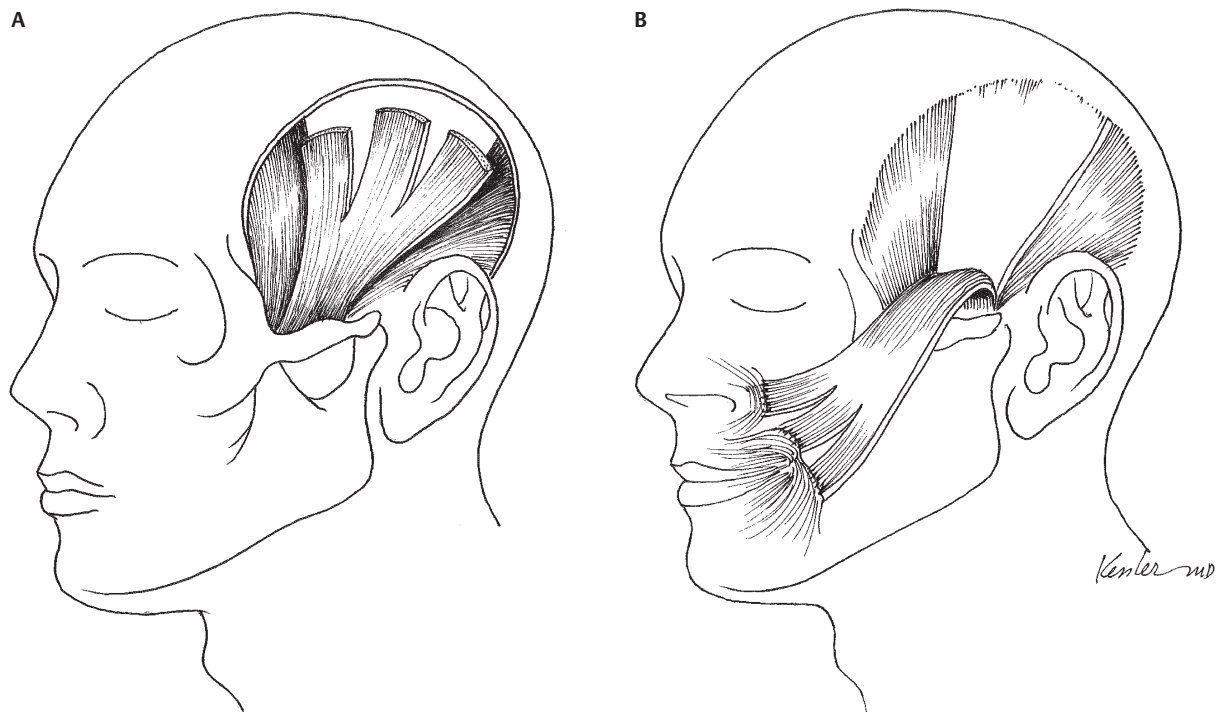


Fig. 8.7 (A) Illustration demonstrating that the temporalis muscle can be divided into several distal strips to address the midface and lower face. (B) Illustration demonstrating the process wherein the sling is performed by transferring the temporalis over the zygoma. The zygoma acts as a lever to provide dynamic facial movement on clenching.



Fig. 8.8 Clinical case. The temporalis muscle has been divided into three distal strips. The strips are secured with nonabsorbable suture and then drawn through the subcutaneous tunnel to approximate with the orbicularis oris and nasolabial fold.

distal aspect of the muscle can be divided to provide an equal distribution of tension across the midface (**Fig. 8.8**).

Surgical Technique and Considerations

- ◆ The origin of the fan-shaped temporalis muscle is the periosteum of the lateral temporal fossa. The muscle tapers to a muscular tendon where it inserts onto the coronoid process deep to the zygomatic arch.
- ◆ To expose the temporoparietal fascia and the temporalis muscle, an incision is made above the ear and carried superior to form a Y.
- ◆ Before exposing the muscle, we raise the temporoparietal facial separately so that it can be used to fill the donor-site defect left when the temporalis muscle is harvested. Once the temporoparietal fascia is raised, the muscle is exposed and prepared for harvest (**Fig. 8.9**).
- ◆ Once the muscle has been exposed, a small template can be created or a marking pen can be used to plan out the muscle harvest. The muscle harvest design is predicated on the goals of the operation. A fan of muscle can be designed to reanimate the lower orbicularis oris, the midface, or the orbicularis oculi.
- ◆ After the muscle flap has been designed, the muscle should be harvested with pericranium at the end of the slips to reinforce the distal suture line.
- ◆ A tunnel should be created superficial to the superficial musculoaponeurotic system (SMAS) from the zygoma to the vermillion border. This tunnel can be extended to a separate incision in the melolabial crease to address the midface (**Fig. 8.10**).



Fig. 8.9 Clinical case. The temporalis muscle is transferred over the zygoma and three 3.0 nonabsorbable sutures are attached to the distal strips of the temporalis muscle to address the middle and lower facial paralysis. The temporoparietal fascia is harvested and displaced posteriorly to be used to fill the defect that results from the temporalis muscle harvest.



Fig. 8.10 When the temporalis muscle is positioned, the second molar should be exposed. Over the course to 2 to 3 weeks the muscle will extend and the commissure will relax into a more normal anatomic position. In this photo, the temporoparietal fascia has been placed into the temporalis muscle defect to minimize the lateral deformity.



Fig. 8.11 Preoperative facial palsy.



Fig. 8.12 The postoperative result after temporalis sling. The facial symmetry is acceptable and the nasal deviation is minimal.

- ◆ The temporalis muscle is then passed through the tunnel and bisected or trisected to address the superior and inferior aspects of the orbicularis oris and the midface.
- ◆ The distal aspect of the temporalis should be tagged with 3.0 nonabsorbable sutures placed in a figure-eight fashion. The sutures, with the attached muscle, are then drawn through the subcutaneous tunnel to the orbicularis and midface incisions, where they are anchored with figure-eight sutures.
- ◆ Overcorrection is exceptionally important. The second molar should be exposed because the muscle tension will release and lengthen over a 4-day period.
- ◆ The temporoparietal fascia can then be placed into the donor muscle defect to prevent the characteristic donor-site depression in the lateral temporal fossa.
- ◆ The preoperative appearance (**Fig. 8.11**) and final postoperative result (**Fig. 8.12**) demonstrate the improvement in facial symmetry.

Patient Selection and Perioperative Management

The temporalis muscle transfer procedure requires an intact ipsilateral fifth cranial nerve, third division (V3). The nerve supply to the temporalis lies along the deep surface of the muscle, and blood supply derives from the deep temporal vessels, branches off the external carotid artery. This neurovascular complex must be intact to perform the temporalis muscle transfer. The procedure is indicated for patients with midface and lower face paralysis. Although this technique has been applied to reanimation of the eye, the results have been unreliable in our hands.

Postoperatively, patients may have a bulge as the temporalis passes over the zygoma. This can be minimized if only a small section of the muscle is harvested; we recommend that the middle section be harvested. Some have advocated placing the temporalis muscle below the zygoma; however, this diminishes the lever mechanism that the zygoma provides as the muscle contracts. We have not found this technique as effective as when the muscle is passed over the zygoma. Over the course of 4 to 7 days, the muscle will lengthen and the commissure will fall. For this reason, overcorrection is essential. The patient and family should be made aware of the initial cosmetic deformity in the immediate postoperative period.

◆ MANAGEMENT OF THE LOWER FACE: MICROVASCULAR TECHNIQUES

Option for Management: Gracilis Muscle Reconstruction with Cross-Facial Nerve Graft

Gracilis muscle reconstruction can be performed as a direct reinnervation technique innervated from the ipsilateral proximal facial nerve or as a cross-face nerve graft technique. Most surgeons have found that both procedures provide optimal long-term results when used in the first 6 months following the injury.³ Using the proximal stump of the facial nerve is appropriate for cases where the facial nerves and facial muscles have been resected as part of an ablative procedure. When the proximal stump is not available, a cross-facial nerve graft is an option.

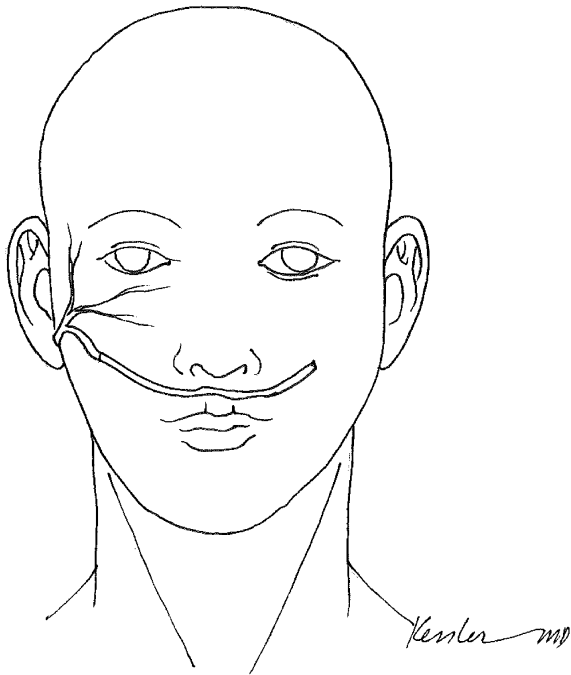


Fig. 8.13 The cross-facial nerve graft. The buccal branch from the side of the intact facial nerve is isolated and prepared for a microneural anastomosis. A microneural anastomosis is performed between the buccal branch and the nerve graft. The nerve graft is passed through a tunnel either above the upper lip or below the lower lip, to the contralateral side of the face.

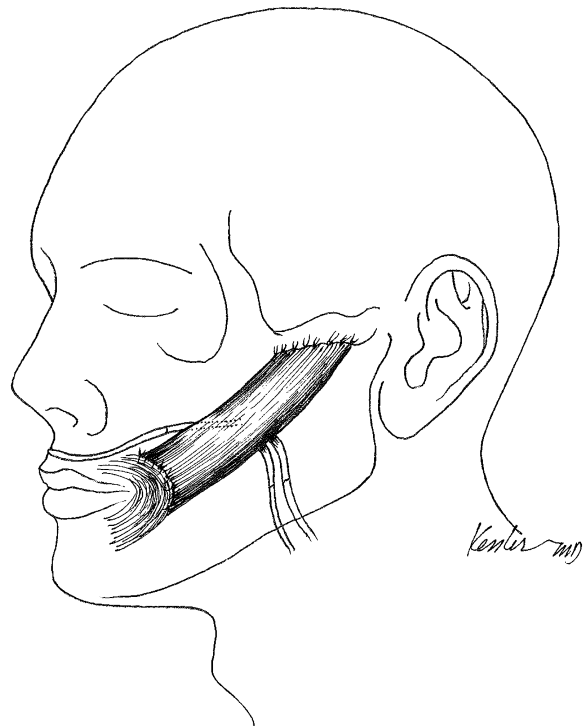


Fig. 8.15 Once the nerve graft has regenerated to the contralateral side of the face, the gracilis muscle can be established. The neural and vascular anastomoses are completed.

Surgical Technique and Considerations (Figs. 8.13, 8.14, and 8.15)

- ◆ The procedure requires two stages.
- ◆ In the first stage a nerve graft is harvested from either the sural or antebrachial cutaneous donor site.
- ◆ The buccal branch from the side of the intact facial nerve is isolated and prepared for a microneural anastomosis.

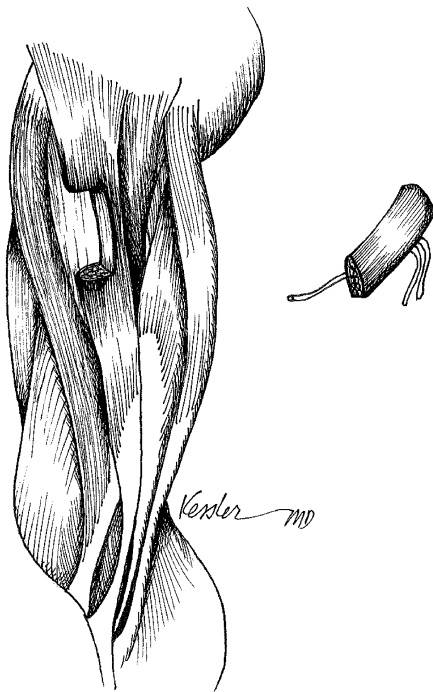


Fig. 8.14 The gracilis muscle is harvested with the obturator nerve for facial reanimation.

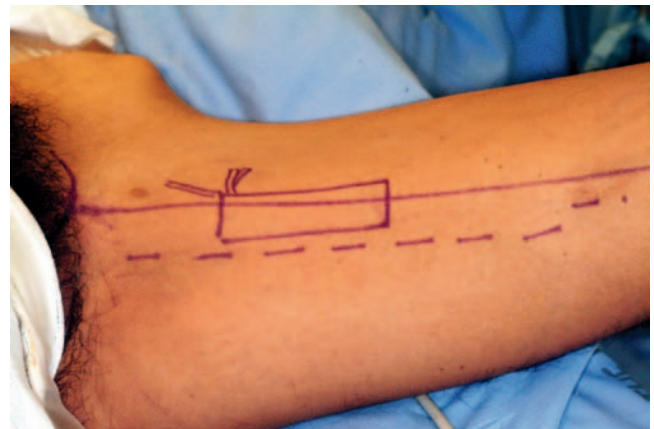


Fig. 8.16 Clinical case. The gracilis muscle harvest.

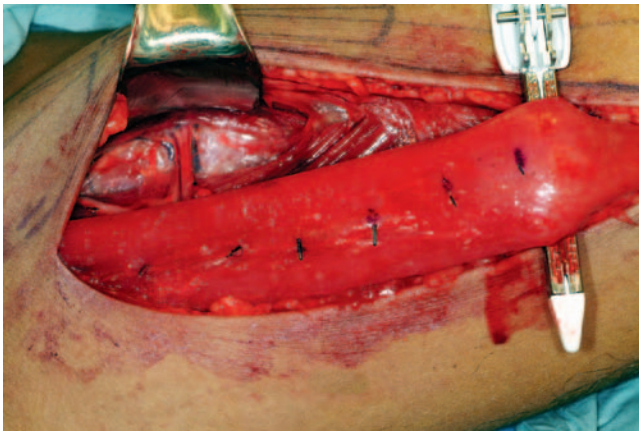


Fig. 8.17 The gracilis muscle should be measured and marked before it is harvested because after the harvest, the muscle will contract, making it difficult to judge the appropriate length of muscle that should be used for the reanimation. The muscle can be harvested with a stapler to aid in retention of the anchoring sutures.

- ◆ A microneural anastomosis is performed from the buccal branch and the nerve graft.
- ◆ The nerve graft is passed through a tunnel either above the upper lip or below the lower lip, to the contralateral side of the face.
- ◆ Neural regrowth within the grafted nerve is monitored by recording progression of Tinel's sign along the path of the graft. This process may take 9 to 12 months.
- ◆ When reinnervation of the graft has occurred, microvascular muscle transfer is then performed (**Figs. 8.16, 8.17, and 8.18**).
- ◆ Nutrient vessels for the gracilis muscle are not particularly long; therefore, the gracilis muscle is best utilized when the superficial temporal and/or facial vessels are used for microvascular anastomosis.



Fig. 8.18 Following the harvest, the muscle contracts. The measured markings can be used to accurately estimate the length of muscle that should be used to suspend the face. Note the short vascular pedicle.



Fig. 8.19 Long-term result of a patient with a history of an isolated middle and lower face paralysis. The patient in repose has good facial symmetry.

- ◆ Clinical muscular contraction and volitional motion may take 12 to 18 months (**Figs. 8.19 and 8.20**).

Patient Selection and Perioperative Management

The direct nerve innervations technique requires that the proximal facial nerve stump be available and in good condition. Facial nerve paralysis secondary to a proximal injury does not provide the proximal nerve stump necessary for this technique and a cross-face nerve graft may be considered. When facial nerve input is not available, alternative nerves can be used for input, including the masseteric branch of V3, ansa hypoglossi, or the hypoglossal nerve.^{4,5}



Fig. 8.20 Patient on smiling produces excellent contraction and symmetry.

◆ CONCLUSION

Before embarking on facial reanimation, a thorough discussion with the patient regarding his or her goals is essential. Although in some patients a static sling is appropriate, others have high expectations. This discussion should also cover the limitations of secondary reanimation. All too often, patients are led to believe that complete volitional movement can be restored. A miscommunication can lead to disappointment and dissatisfaction. Every patient should understand that nerve regeneration is not predictable, but what is predictable is that complete volitional symmetry is not typically achievable given the current methods of reconstruction. A well-informed patient will usually be a satisfied patient.

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Pediatric Head and Neck Reconstruction

Eric M. Genden and Marita Teng

The majority of diseases affecting the upper and lower jaws of children are benign.¹ Consequently, the surgical resection of such diseases requires only narrow margins and, in turn, commonly necessitates minimal reconstruction. In some cases, however, larger resections resulting in a significant deformity may be necessary to obtain appropriate disease-free tissue margins. In cases that result in a significant bony defect, the options for reconstructing the jaw include non-vascularized bone grafts and vascularized composite flaps. For select defects, nonvascularized bone grafts may provide a simple method of bony reconstruction, assuming the surrounding tissue bed is well vascularized and the patient has a good nutritional status. Occasionally, however, the patient has been previously exposed to chemotherapy or radiation, or has sustained a significant bony defect, requiring a vascularized bone flap.

A variety of childhood diseases may affect the mandible or maxilla; however, sarcomas are the most common form of malignancy.² Although surgical resection plays an important role in the treatment of this disease, most often these patients have been previously treated with chemotherapy, radiation, or combination therapy. As a result, the recipient bed is often compromised with regard to healing,^{3,4} thus limiting the application of adjacent tissue transfer or nonvascularized bone grafts. Although strategies to minimize the effect of chemotherapy and radiation on the healing of soft tissue and growth of the craniofacial skeleton have been investigated,³ under these circumstances free vascularized tissue remains the most reliable source of bone and soft tissue.

When a surgical resection of the pediatric patient is indicated, prompt reconstruction is essential to both long-term psychological well-being^{5,6} and normal craniofacial development.^{3,4} Over the last decade, there has been a trend to embark on early surgical reconstruction of children with craniofacial disorders, which has resulted in a series of reports investigating the role of surgical reconstruction on psychological development.^{5,7} Many of these studies were prompted by a common anecdotal experience among reconstructive surgeons that children who underwent early

reconstruction of craniofacial deformities seemed to socialize postoperatively with their peers and their parents in a more positive way than did their unreconstructed counterparts. Early studies by Pertschuk and Whitaker⁸ supported these experiences, demonstrating an increase in self-esteem and peer acceptance following surgery. Examination of the long-term effects of facial disfigurement on social development has demonstrated convincing evidence that attractiveness plays a definitive role in normal socialization patterns, and that children with unreconstructed craniofacial deformities are more prone to an inhibited personality style, low self-esteem, and impaired peer relationships.⁹ It has been postulated that these children harbor a poor self-image at an early age, resulting in the development of antisocial behavior in adolescence.⁹ Similarly, it has been suggested that adults have lower expectations of disfigured school-age children, leading to underachievement, social withdrawal, and occasionally depression.¹⁰ When early surgical intervention occurs, however, these children tend to psychosocially adjust in a rather short period of time. Commonly, both peer and family interactions occur more naturally as these children resolve their avoidance disorders.^{5,6,8}

In addition to a healthy psychological development, a normal physical development is important in the lives of these patients. Although mandibular and maxillary reconstruction in children is uncommon, when faced with this challenge it is essential that special consideration be given to issues related to the growing child, so that the goal is to achieve optimal restoration of mastication, deglutition, and cosmesis. Similar to reconstruction of the adult mandible, bone stock, soft tissue, and skin paddle design are important factors in addressing the specific reconstructive requirements of the patient. In contrast to the adult patient, however, the pediatric patient is growing. Because of this characteristic unique to this population, surgical reconstruction of the upper and lower jaws requires an understanding of the changes in bone and soft tissue architecture at both the donor site and the mandibulofacial complex as a result of growth and development. The commonly used donor sites,

including fibula, iliac, and scapula, all possess growth centers, areas of the bone that monitor and regulate growth and development. Disruption of the growth center as a result of bone flap harvest can lead to abnormal development and long-term functional consequences. Understanding the anatomic location of these growth centers and their role in normal development is essential to preventing long-term functional deficits.

Similarly, the process of craniofacial development is a dynamic one in which mandibular, maxillary, and basicranial growth are intimately interrelated. The disruption of these relationships, as occurs with a mandibular or maxillary ablation, can result in abnormal development of the midface, mandible, and skull base, leading to profound orodental consequences. Restoration of these relationships with free flap reconstruction, however, can reestablish mandibulomaxillary occlusion and condylar-basicranial articulation, leading to normal craniofacial development and oromandibular function.

In the adult patient, the selection of a donor site is based on factors such as the requirements of the defect and the patient's comorbidities.¹¹ The pediatric patient, however, is usually healthy and in good nutritional status. Although issues related to tissue requirements for restoration of the defect are important in choosing a donor site, there is an additional parameter that is of critical importance: the long-term development at the reconstructed site as well as the donor site.

◆ NORMAL DEVELOPMENT OF THE UPPER AND LOWER JAWS

Normal craniofacial development, including growth of the mandible and maxilla, results from a series of complex mechanisms that have been the focus of intense debate among investigators and clinicians. Facial growth is a dynamic process that Enlow¹² refers to as the “ongoing equilibrium” that exists among the skull base, muscle stress, and occlusal relationships. After birth, the pediatric craniofacial skeleton grows through two distinct mechanisms: epiphyseal proliferation and bone remodeling. Epiphyseal proliferation is largely responsible for increases in bone length and projection (Fig. 9.1), a process that is dominant during the first 18 years of life. After age 18 the epiphyseal plate of the mandible, which is located in the proximal zone of the conical subcondylar ridge, fuses. Consequently, the majority of the longitudinal growth in this region is complete. Prior to fusion, however, the epiphysis exists as a three-dimensional structure responding to the influence of the surrounding soft tissues, traction forces of the muscles of mastication, and the condylar relationship with the cranial base. During the course of facial skeletal development, the mandibular epiphysis adapts the intercondylar distance to the widening cartilaginous synchondrosis of the cranial base, highlighting the ever-important relationship between normal mandibular growth and normal basicranial development. A disruption of the epiphysis, the muscles of mastication, or the temporomandibular joint prior to the fusion of the epiphyseal plate, can result in abnormal mandibular

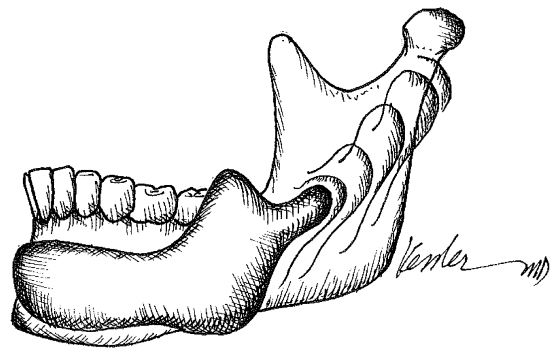


Fig. 9.1 The projection and growth of the mandible is a result of epiphyseal growth demonstrated by the growth and extension of the condylar neck.

projection and malocclusion.¹³ The role of epiphyseal growth, particularly in the prepubescent pediatric patient, cannot be overemphasized; however, a second mechanism of bone growth called remodeling, plays an equally important part in mandibular contour and symmetry.

In contrast to epiphyseal growth, remodeling is a process that occurs both during the prepubescent period and throughout adulthood. Adjustments in the downward and forward projection of the mandible occur through deposition of bone at the posterior margin of the ramus along with corresponding resorption at the anterior margin.¹² Likewise, mandibular contour and increased width occur as a function of buccal bone deposition and concomitant lingual resorption. The two simultaneous processes of epiphyseal growth and bone remodeling occur in different areas within the same bone simultaneously, and there is no histologic difference in new bone created by either process. Although epiphyseal fusion occurs in early adolescence as part of a genetically preprogrammed process, remodeling continues throughout adult life largely in response to the mechanical stress applied by the muscles of mastication (Fig. 9.2).¹⁴⁻¹⁶

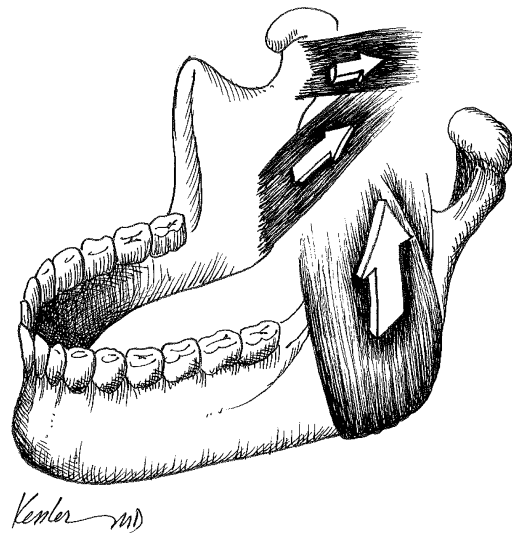


Fig. 9.2 Mandibular and maxillary growth occur throughout development. The growth is stimulated by muscular and mastication stress. If there is a breakdown in this stimulation, growth will be disrupted.

Understanding these principles is important in surgical reconstruction because disruption of the mandible prior to epiphyseal fusion may result in a different long-term developmental abnormality from a similar surgical disruption after epiphyseal fusion. Furthermore, it is important to recognize that girls reach mature mandibular height and depth at a mean age of 13, on average, which is 2 to 5 years earlier than do boys.

The maxilla serves as the infrastructure of the midface; however, it also plays an important role during facial development by providing an occlusal surface for the mandible. This occlusal relationship functions as a feedback loop that helps to guide both midface and mandibular development. The ultimate form of the midface is a result of two separate but related processes. The first is referred to as primary displacement, or growth of the maxilla bone itself, and the second is secondary displacement, or movement of the maxilla as a result of growth of the surrounding articulating skeleton.¹² Primary displacement results from the genetic propensity for the maxillary bone to enlarge as a child ages, therefore contributing to vertical maxillary growth. During this process, periosteal resorption occurs on the nasal side of the palate, whereas periosteal deposition occurs on the oral side of the palate. This leads to a downward projection of the maxilla and an enlargement of the nasal chambers. Normal maxillary width occurs as a result of bony accretion at the suture lines and resorption at the lateral nasal wall. Secondary displacement is characterized by growth of the surrounding craniofacial skeleton, namely the skull base and the mandible, which serve to further displace the maxillary complex downward and forward. Normal dental occlusion acts to guide maxillary projection and preserve both the cosmetic and functional harmony of the midface. Although primary and secondary displacement are essential to normal maxillary growth, a third mechanism is equally important in the development process. The traction forces associated with the muscles of mastication and the axial loading forces associated with mastication also contribute to the development process. A disruption in any or all of these growth mechanisms prior to skeletal maturation inevitably leads to a morphologic change in maxilla. Vertical maxillary growth is normally complete by age 14 in girls and age 16 in boys, and fusion between the palatine processes and the maturation of maxillary width occurs at 18 years of age.

Much of what is known about facial development after ablative surgery is derived from experimental animal models.¹⁷ It is clear, however, that disruption of the developing maxilla or the maxillary suture lines prior to fusion will significantly affect midface development. When disruption of the pediatric midface hinders normal occlusal contacts, there may be a profound effect on both mandibular and maxillary development. Occlusal contact provides bone stress, a key component to the induction of bone growth; therefore, the occlusal interaction between the maxilla and the mandible is paramount to ensure normal craniofacial development. It is for this reason that unreconstructed defects of the pediatric maxilla can lead to significant disturbances in facial growth and aesthetic form.

DONOR-SITE SELECTION

The Fibular Donor Site

Although the developmental implications of performing a surgical ablation on a pediatric patient may be profound, if careful consideration is not given to the reconstruction, the morbidity associated with a donor-site harvest may be equally disturbing. Three donor sites have been applied to pediatric mandibular and maxillary reconstruction: the fibula, the scapula, and the iliac crest.^{18,19} Fibular growth, which has been studied quite extensively, occurs in a classic endochondral pattern as the three ossification centers (one in the shaft, and one in each of the distal and proximal epiphyses) are responsible for proportionate growth (**Fig. 9.3**). The growth plates lie within 1 to 2 cm of each end of the bone, proximal and distal to where a harvesting osteotomy is commonly made. The majority of growth occurs in the

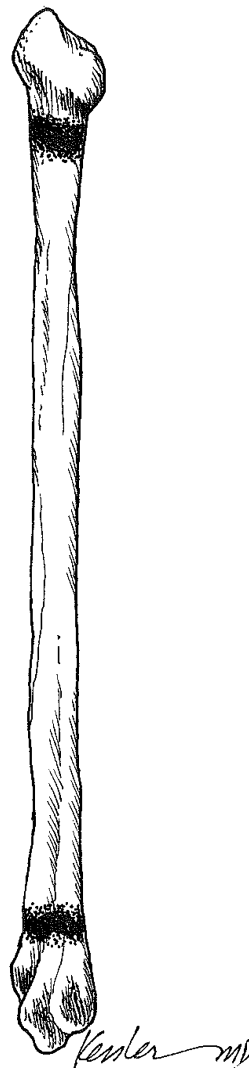


Fig. 9.3 The fibular growth plates lie within 1 to 2 cm of each end of the bone, proximal and distal to where a harvesting osteotomy should be made.

proximal epiphyseal plate that fuses by age 15 in girls and age 17 in boys.²⁰ Similar to that in the adult, the fibula offers the longest segment of bone of the three donor sites; however, the stock of bone, particularly in patients under the age of 13, may lack the height appropriate to stabilize osseointegrated implants. In such cases, the fibula can be “double barreled”²¹ by creating a midpoint osteotomy and

folding the bone upon itself. This results in an increase in the bone height and a more stable foundation for osseointegrated implants (**Fig. 9.4**). The double-barreled fibula can be secured upon itself by placing a vertical lag screw or circumosseous wires at each end of the complex.

Essential to achieving a successful long-term reconstruction, transferred bone must grow at a rate similar to that of

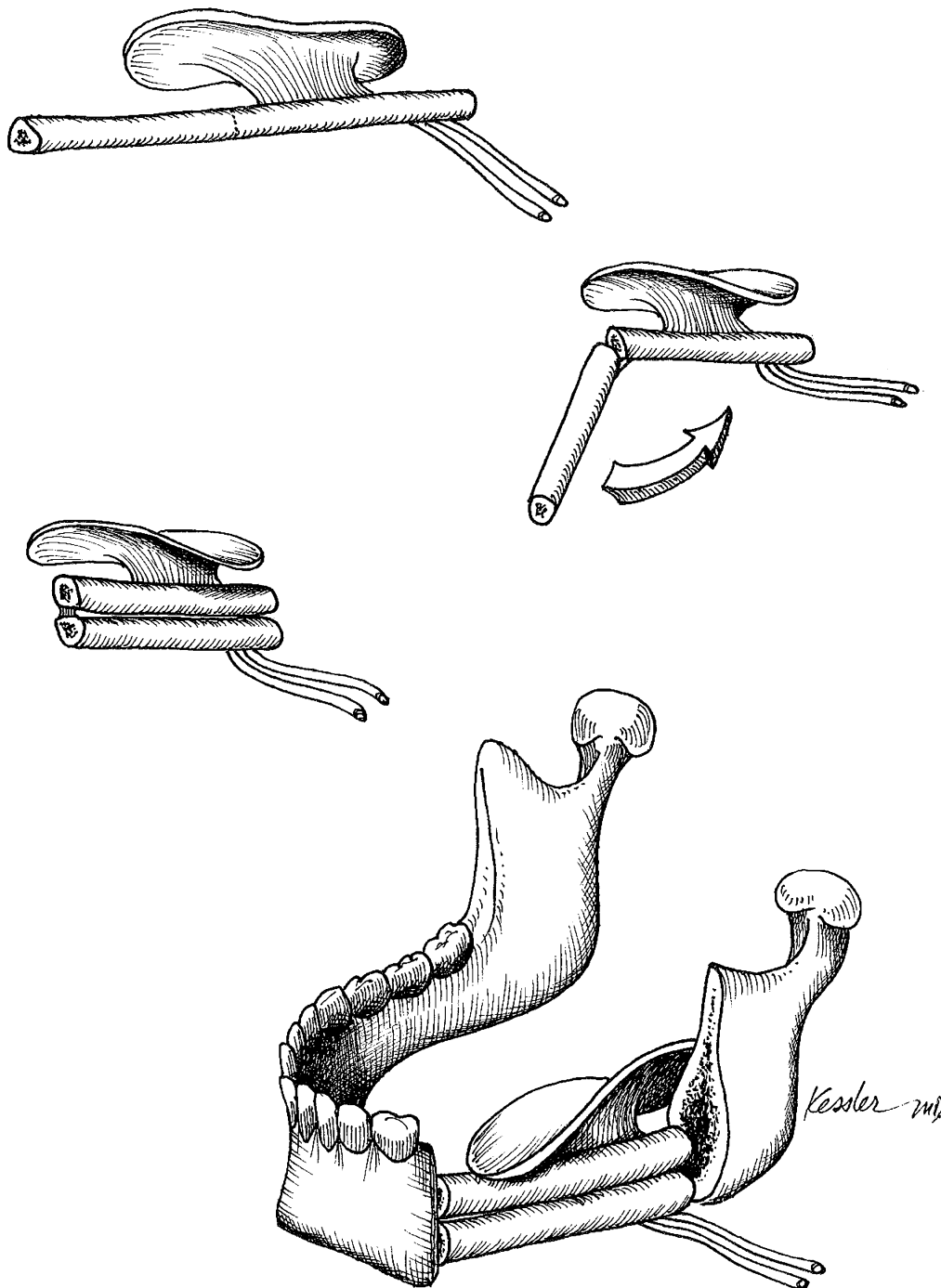


Fig. 9.4 The stock of bone of the fibula, particularly in patients under the age of 13, may lack the height appropriate to stabilize osseointegrated implants. The bone graft can be “double barreled” to increase bone stock height. This is helpful for the eventual placement of osseointegrated implants.

the native mandible or maxilla. Concern regarding growth of the transferred bone, particularly in a developing child, has led investigators to find the ideal transplantable epiphysis. Epiphyseal transfer in the iliac and fibula has proven successful in the treatment of epiphysiodesis and acetabular defects in children; however, the necessity to transfer an epiphysal growth plate in jaw reconstruction has not been clearly demonstrated.^{22–24} Epiphysal plates are not routinely transferred during the harvest of the fibula; however, the fibula will continue to grow at a rate comparable with that of the adjacent native mandible (**Fig. 9.5**).^{25–28} It is likely that this occurs because a growth center remains within the shaft of the transferred bone. It has been shown experimentally, however, that when an epiphysal plate is transferred in a vascularized bone segment, it retains the potential for growth.^{26,29} Although it has not been reported clinically, this may serve as a potential source for condylar reconstruction in the prepubescent pediatric patient.

Harvesting the fibula from a growing limb has raised concerns among reconstructive surgeons; however, there is little clinical evidence that suggests long-term limb growth is adversely affected.^{18,30} Although experimental evidence in rats suggests that the fibula exerts a restrictive effect on tibial growth such that removal of the fibula leads to longitudinal tibial overgrowth,²⁸ we have not observed this clinical phenomenon in our series.¹⁸ The most significant delayed complication associated with fibular harvest, particularly in children under the age of 8, is the development of a valgus deformity.^{30,31} An ankle valgus may result from a variety of etiologies including multiple hereditary exostoses, poliomyelitis, congenital pseudarthrosis of the fibula, and fibular harvest. When it does occur, it can lead to chronic pain syndromes and a profound gait disturbance. Several strategies



Fig. 9.5 Clinical case. Two years following a fibular reconstruction of the hemi-mandible, growth and symmetry are stable.

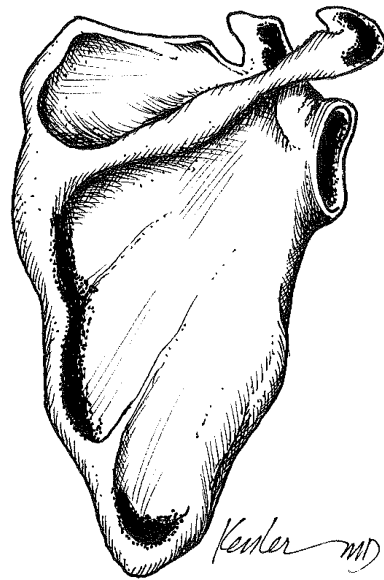


Fig. 9.6 Ossification of the scapula proceeds in a superior to inferior pattern until approximately age 10, when the scapula is roughly 12 cm long and the distal epiphysis has decreased to only 4 cm. A smaller but equally important growth plate exists superiorly, adjacent to the glenoid fossa.

have been proposed for both the prevention and the management of this deformity, including partial epiphysiodesis with staples, tibiofibular (TF) synostosis, and transphyseal fibula-tibial screw.³¹ Omokawa et al³⁰ reviewed 13 cases of pediatric fibular harvest in which patients were divided into two groups: one received a TF synostosis and the other did not undergo a synostosis. The postoperative observation period ranged from 5.8 years to 16.5 years. In the former group, a valgus deformity was observed in only one patient, whereas in the latter group all of the children under the age of 8 years developed a valgus deformity. Irrespective of the method of tibiofibular stabilization, it is clear that in children under 8 years of age who did not undergo a synostosis, the prevention of a valgus deformity is essential following fibular harvest.

The Scapular Donor Site

Unlike the fibula, the scapula is a flat membranous bone; however, the lateral scapular border is analogous to a long bone whose distal end is formed by a large osteocartilaginous epiphysal plate. At birth, the distal 7 to 8 cm of the scapula are composed entirely of hyaline cartilage, and it is this osteocartilaginous apophysis that is responsible for the development of four fifths of the scapula.³² Ossification proceeds in a superior to inferior pattern until approximately age 10, when the scapula is roughly 12 cm long and the distal epiphysis has decreased to only 4 cm (**Fig. 9.6**). A smaller, but equally important growth plate exists superiorly, adjacent to the glenoid fossa.³² Mainly responsible for vertical scapular growth, the superior growth plate lies outside the range of harvested bone, and therefore should not be directly affected. Both superior and inferior growth plates fuse at

approximately age 20, so that normal scapular development is disrupted after harvesting bone from the distal scapula in the pediatric patient. Similarly, the lateral border of the scapula serves as a traction epiphysis, growing in response to traction by the teres and triceps muscle groups.²⁹ A disruption in the muscular attachments or a disruption in the lateral scapular border, may lead to an arrest in scapular development. Concerns regarding the long-term consequences of a bone harvest in this region have been addressed by Teot et al,³² who examined a series of three patients who had undergone scapular free flap reconstruction of congenital limb amputation. They found that harvesting bone from the lateral border and distal scapula resulted in a moderate scapular size discrepancy. They compared plain radiographs of the operated scapula with the nonoperated scapula 5 years postoperatively, and found that although there was a 3-cm discrepancy in scapular length as a result of arrested growth, there was no appreciable limitation to range of motion or strength when compared with the contralateral scapula. They concluded that the upper growth plate must compensate for disruption of the scapular epiphysis, although there is no objective data to support this claim. Similarly, in our series we have found that pediatric patients recover completely following harvest from the scapular donor site. With the aid of physical therapy, full range of motion and strength are recovered within 6 weeks.¹⁸

The scapular donor site has been used quite extensively for pediatric limb reconstruction; however, it has not been commonly used for pediatric jaw reconstruction. Although the presence of an active epiphysis as part of the bone graft has a theoretic advantage for reconstructing a growing patient, this issue has not been carefully studied. Because it has been shown that transferred epiphyseal bone will continue to grow at a rate that is linearly related to the amount of stress applied to that bone,¹⁶ it is important to achieve orodental rehabilitation as soon as possible. Although the lateral border and distal tip of scapula provide bone adequate for the retention of osseointegrated implants in adults,³³ the pediatric scapula may be quite thin and limit implant stability. In this situation, nonvascularized onlay bone grafts placed either primarily or secondarily may be used to augment the scapular bone to facilitate implant stability. The placement of implants followed by implant-borne dentures will in turn provide the bone stress necessary to stimulate continued bone growth.

The Iliac Donor Site

The entire length of the iliac crest, from the anterior-superior to the posterior-superior iliac spines, is composed of cartilage at birth. Growth occurs in an epiphyseal fashion in several areas of the pelvic girdle, including the acetabulum and the iliac crest, which grow until the second decade of life (Fig. 9.7). The mechanical demands applied to the pelvis by both its upper and lower muscular attachments play an integral role in pelvic remodeling, which occurs into young adulthood. A disruption in the epiphysis prior to its fusion may have a profound effect on the development of the pelvic girdle. Rossillon et al³⁴ reviewed 21 children over an average

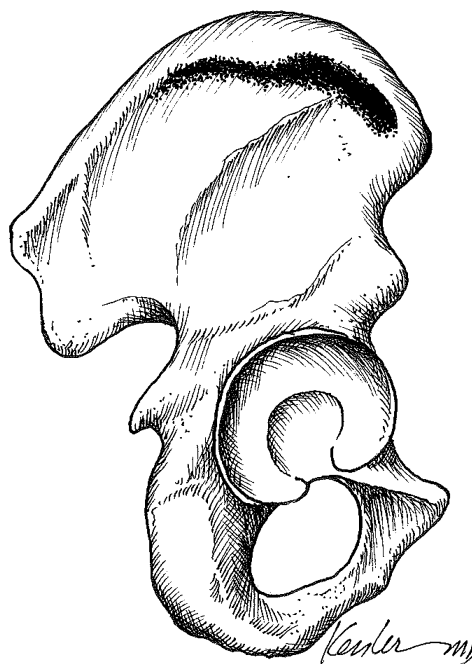


Fig. 9.7 Growth of the iliac occurs in an epiphyseal fashion in several areas of the pelvic girdle including the acetabulum and the iliac crest, which grow until the second decade of life.

of 3 years and 10 months who had undergone a surgical disturbance of the iliac epiphysis. They demonstrated that 16 of these children developed iliac hypoplasia as a result of premature arrest in growth; however, no functional evaluation was performed on the children in this series.

Like the lateral scapular border, the iliac crest serves as a traction epiphysis where the dynamic interaction between the iliac crest and its muscle attachments play a crucial role in acetabular development and hence gait stability. Lee et al³⁵ examined the effect of an injury of the iliac apophysis on the subsequent growth of the pelvis. They examined immature New Zealand rabbits and found that excision of any more than one third of the iliac apophysis resulted in retarded growth of the iliac bone. A similar study by Olney et al³⁶ found that a lesser injury, such as a splitting of the iliac apophysis, was enough to adversely affect normal iliac development. In the adult population, disturbance of gait after iliac crest free flap harvest has been documented in up to 11% of patients^{37,38}; however, there is little published on the long-term effects of iliac crest harvest in the pediatric population. Boyd¹⁹ reviewed five patients between the ages of 16 and 27 years who had undergone mandibular reconstruction using a free vascularized iliac crest free flap. He found minimal donor-site morbidity in his series of young adults; however, the youngest patient in his series was 16 years old. Although this donor site has been suggested as ideal for pediatric mandibular reconstruction,³⁹ the probability of postoperative gait disturbance in a younger age group has discouraged most surgeons from utilizing this donor site. As a result, there are no reported series of iliac crest free flap reconstructions in the prepubescent pediatric population.

◆ GROWTH OF VASCULARIZED BONE GRAFTS

Although fibular and scapular flaps have been used quite extensively by plastic surgeons for the reconstruction of acquired and congenital limb abnormalities, there is little reported on the long-term growth of the transferred bone after mandibular and maxillary reconstruction. Although one may consider that the information gleaned from pediatric extremity reconstruction can be applied to bone growth in the reconstructed jaw, it is not clear that these principles can be universally applied. There is good evidence that osteocyte viability is preserved after the transfer of non-epiphyseal-containing vascularized bone grafts^{25–28}; however, the bone growth may be unpredictable. Experimental evidence suggests that vascularized membranous bone grafts utilized in the reconstruction of mandibular and zygomaticomaxillary defects in immature animals contribute to normal craniofacial development in a more predictable fashion than nonvascularized bone grafts,⁴⁰ but there is little evidence to support this clinically. It has been speculated that the growth of transferred bone grafts is influenced by the adjacent craniofacial skeleton. We have seen symmetrical maxillary and mandibular growth in pediatric patients reconstructed with both scapular and fibular free flaps; however, the influence of the native craniofacial bone on bone graft growth is a difficult relationship to establish. Clearly, the proven linear relationship between bone stress and bone growth¹⁶ may be responsible for symmetrical growth of the transplanted bone, making this issue particularly complicated.

◆ CONCLUSION

Pediatric reconstruction is relatively rare. Although most of the concepts for adult reconstruction hold true for the pediatric patient, the potential for donor-site morbidity is unique in the pediatric population. The knowledge of growth plate and ossification centers is important in limiting donor-site morbidity.

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10

Microvascular Reconstruction of the Head and Neck

Brett A. Miles

Microvascular reconstruction of the head and neck continues to challenge surgeons worldwide despite significant technical advances. Paramount to successful microvascular reconstructive surgery is appropriate management of the microvascular anastomosis and vascular pedicle. The details of vessel management and microvascular anastomosis are critical to surgical success and are often ignored. This chapter discusses the general considerations and technical details, and provides a framework for successful vessel management for microvascular free tissue transfer in the head and neck.

◆ RELEVANT ANATOMY

The vascular anatomy of the neck is well described, and a complete review of the anatomy is beyond the scope of this chapter. Nevertheless, microvascular surgeons have multiple vascular donor options within the head and neck for microvascular surgery. Essentially, arterial donor vessels may be divided into two categories: branches of the external carotid and branches of the thyrocervical trunk (**Fig. 10.1**). Although major branches of the external carotid artery such as the facial and the superior thyroid provide the majority of recipient vessels in microvascular head and neck reconstruction, anatomic issues, vessel availability, and the technical aspects of the reconstruction often preclude the selection of these vessels. In these situations, and in the situation of the vessel-depleted neck, selection of vessels may require accessing the thyrocervical trunk or branches of the external carotid less commonly utilized by reconstructive surgeons. It is in situations such as these that confusion or poor vessel selection and orientation may occur, resulting in a failed reconstruction. Therefore, understanding the anatomy of the vasculature of the head and neck in the context of the reconstructive goals is paramount for successful free tissue transfer.

With these goals in mind, it is helpful to consider the vasculature of the head and neck in terms of arterial recipient vessel regions or zones. Zone I represents the

superiormost region, including vessels available from the facial artery as it passes lateral to the mandible and superior to this level. Zone II represents the region of available cervical vessels below the mandible and contains the remaining branches of the external carotid, the most inferior being the superior thyroid artery. Zone III represents the most inferior

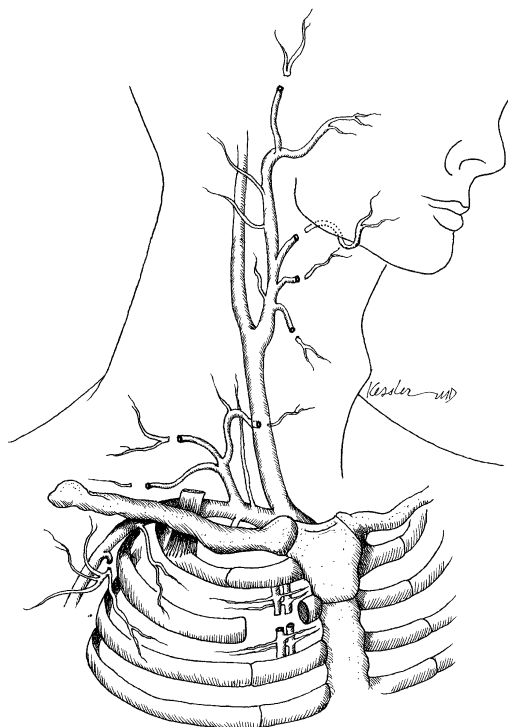


Fig. 10.1 The donor vessels may be divided into two categories: branches of the external carotid and branches of the thyrocervical trunk. Although major branches of the external carotid artery, such as the facial, lingual, and the superior thyroid, provide the majority of recipient vessels in microvascular head and neck reconstruction, the internal mammary, and thoracoacromial systems may be used in challenging cases.

region of recipient vessels, which includes branches of the thyrocervical trunk, thoracoacromial system, and internal mammary artery. It should be noted that these regions are meant to help reconstructive surgeons conceptualize the head and neck vasculature in an organized way, not to guide reconstructive decisions. The region of the planned reconstruction may or may not coincide with the zone of recipient vessel selection. For example, a scalp reconstruction in zone I may in fact also have recipient vessels in zone I (i.e., superficial temporal artery/vein); however, a fibular reconstruction of the mandible (zone I) is likely to have recipient vessels selected within zone II or III. In fact the majority of reconstructions often results in the selection of recipient vessels one or more zones removed from the reconstruction for the optimal pedicle configuration. Some detailed considerations of the recipient zones follow.

Zone I

Recipient vessels within zone I include the facial artery lateral to the mandible, the ascending palatine artery, the angular artery (distal facial artery), the maxillary artery, and the superficial temporal artery. Access to deeper systems, such as the ascending palatine or maxillary artery, generally requires an ablative procedure that exposes these vessels, and they are infrequently utilized due to their anatomic location. Knowledge of the available vessel options within zone I is critical for planning microvascular reconstructions of the nasal complex or anterior forehead/scalp and orbit.

The facial artery and vein passing lateral to the body of the mandible provide excellent caliber and reliability within zone I for microvascular reconstruction. Location of these vessels is readily achieved by palpation of the mandibular notch and careful dissection to identify the vessels for vascular access as well as to identify and protect the marginal branch of the facial nerve, which overlies the facial vein in this region. Distally, the angular/nasolabial branch of the facial artery may be reliably located within the nasolabial fold and has been used successfully for microvascular reconstruction.¹ Cadaveric investigation revealed that the average length of the artery was 28 mm and the mean diameter of the respective artery and vein (1.5 and 2.5 mm) was suitable for microvascular anastomosis in 85% of the sides investigated.² Successful intraoral preparation and microvascular anastomosis has been reported as well and represents an option for intraoral reconstructions when extraoral incisions may be avoided.³

Reconstructive surgeons have utilized the superficial temporal system of the external carotid artery for the reconstruction of facial, scalp, and maxillary defects.^{4,5} This system is often avoided or ignored by many surgeons due to unfamiliarity with the anatomy or concerns about vessel diameter and reliability. The location of the superficial temporal artery is extremely consistent and is approximately 1 cm anterior to the external ear and is readily located with Doppler examination. Advantages of this recipient site include avoiding previously radiated areas, good anatomic reliability, and the avoidance of vein grafting for reconstructions of this region. Dissection of the vessels

often requires some dissection within the superior portion of the parotid gland, and careful attention to avoid damaging the frontal branch of the facial nerve is required. The superficial temporal vein is relatively thin, and careful dissection and avoiding excessive manipulation or kinking during microvascular anastomosis are required. Dissection should proceed immediately subcutaneously in this area until the superficial temporal vein is identified to avoid damaging the vein. Caution should be exercised when selecting these vessels for microvascular reconstruction if the region has received radiation.⁵

Zone II

Recipient vessels located within zone II are the most commonly utilized vessels for microvascular reconstruction of the head and neck. The branches of the external carotid artery (and in some cases the external carotid artery itself) provide excellent caliber and flow characteristics for microvascular reconstruction and have proven to be very reliable in large series of microvascular reconstructions. It should be noted that vessels within zone II are often within the target region of previous radiotherapy for pharyngeal/laryngeal malignancies or metastatic cervical lymph nodes. Vessels that appear to have sufficient diameter may reveal significant intimal/medial thickening due to radiation, and the actual internal diameter may be quite attenuated under microscopic inspection. The reconstructive surgeon must verify adequate flow from the selected vessel prior to arterial anastomosis. As a general principle, selection of the artery with the strongest arterial flow rather than the largest diameter yields more reliable results.

The facial artery is arguably the most commonly used vessel for head and neck microvascular reconstruction. Its favorable location, length, and diameter make it an ideal candidate for microvascular anastomosis within this region. Experienced microvascular surgeons have noted that the tethering of the facial artery by the digastric/stylohyoid muscles may preclude adequate access to the artery or introduce untoward positioning of the vascular pedicle. Division of the digastric muscle is recommended to address these issues.⁶ The lingual artery may be accessed in a similar fashion, and arises slightly inferior to the facial artery from the external carotid artery. Identification of the hypoglossal nerve in this area may be required to provide appropriate vascular access and avoid damaging the nerve.

The superior thyroid artery provides excellent caliber and reliability for microvascular reconstructions. Cadaveric investigations have reported the outer diameter of the superior thyroid artery to be approximately 3.5 mm. It should also be noted that the reported location of the artery in relation to the carotid bifurcation is somewhat variable.⁷ The superior thyroid artery offers an additional advantage of having an inferior orientation relative to the superior orientation of all other branches of the external carotid. Excellent arterial length may be obtained by tracing the artery inferiorly until several branches supplying the thyroid gland are encountered and vessel diameter is compromised. Interestingly, using the superior thyroid artery in a reverse

flow pattern has been reported in the microsurgical literature; however, the reliability of this technique has not been evaluated.⁸

Zone III

Zone III represents the most inferior region of recipient vessels, which includes branches of the thyrocervical trunk, thoracoacromial system, and internal mammary artery. These vessels have been extensively utilized in situations in which zone II vessels are unavailable or are in an unfavorable location related to the reconstruction. The thyrocervical trunk may be identified posterior to the sternal attachment of the sternocleidomastoid muscle deep to the clavicular attachments and deep to the omohyoid muscle. The vessels of the thyrocervical trunk including the inferior thyroid, superficial cervical, and suprascapular artery may be found within the cervical fat overlying the anterior scalene muscle. The deep cervical fascia overlying the anterior scalene muscle should be kept intact during surgical dissection to prevent damage to the phrenic nerve. Prior to arterial division within this region the surgeon should verify that a branching pattern exists on the proposed recipient artery as the vertebral artery arises slightly medial to the origin of the thyrocervical trunk from the subclavian artery and may inadvertently be damaged, with severe consequences. The thyrocervical system represents the ideal arterial system for microvascular surgeon in the vessel-depleted neck. It is important to note that the microvascular surgeon may wish to access the thyrocervical system for microvascular anastomosis merely to optimize pedicle orientation despite the availability of external carotid recipient vessels.

◆ PREOPERATIVE CONSIDERATIONS

The preoperative assessment of patients who are to undergo microvascular free tissue transfer is important to successful surgical outcomes. The impacts of medical comorbidities and of age, to some degree, are recognized by microvascular surgeons and frequently alter the management considerations when free tissue transfer techniques are employed.⁹⁻¹¹ Previous radiation therapy has been reported to be a positive predictor for wound complications after microvascular reconstruction; however, the impact of these therapies continues to be investigated, and although an adverse effect may be suspected, debate regarding the actual effects of radiotherapy continues.¹²⁻¹⁴ The implications of body habitus and general anatomic factors are frequently ignored by inexperienced surgeons but may have a significant impact during free tissue reconstruction. Obesity, short neck, radiation fibrosis, and cervical osteoarthritis may impair the ability of the microsurgeon to harvest, inset, and orient the microvascular reconstruction in a favorable configuration.¹⁵ Tunneled vascular pedicles, which may be performed routinely in patients with normal body habitus, may represent significant technical challenges in obese patients, resulting in untoward twisting and stretching of the vascular pedicle.

Knowledge and selection of appropriate flaps with long vascular pedicles to relieve tension, consideration of vein grafting, or altering operative approaches to improve access may address these issues.

Review of previous operative reports can yield information related to the vasculature available for microvascular anastomosis. Additionally, operative details may offer insight into the difficulties that may be encountered when additional procedures are performed. Procedures such as neck dissections, thyroidectomy, submandibular gland surgery, tracheostomy, carotid endarterectomy, and previous cervical spine surgery via an anterior approach may not preclude the availability of a microvascular vessel but will undoubtedly have some level of impact on operative findings when performing free tissue transfer. Previous microvascular reconstruction will have an obvious impact, and operative reports related to previous free tissue transfers should be carefully reviewed. Although the focus of the microsurgeon includes the location of suitable vessels for microvascular reconstruction, often other technical issues as noted above dominate the surgical challenge and lead to complications postoperatively. Therefore, it is important for the reconstructive microsurgeon to have mastery of the anatomic considerations and a wide variety of reconstructive options available to address the multitude of challenges that may arise during surgery. More importantly, the microsurgeon must recognize the inherent factors present in each individual patient to allow for adequate preoperative planning and maximize success.

Imaging Studies

Although the routine use of preoperative imaging in the surgical planning for ablative surgery is widely accepted, preoperative imaging obtained specifically for microvascular surgery is often unnecessary. There are, however, several situations in which imaging is indicated prior to reconstruction. Perhaps the most obvious indication for preoperative imaging is the assessment of peripheral vessels in fibular surgery in patients with longstanding peripheral vascular disease. Computed tomography (CT) or magnetic resonance angiography (MRA) (or formal flow Doppler investigation) should be considered to evaluate the lower extremity vasculature in patients with appropriate risk factors undergoing fibular free transfer.¹⁶⁻²⁰ The routine use of angiographic studies for the detection of peroneal artery septocutaneous perforators continues to be evaluated; however, it is probably unnecessary in the majority of cases.^{21,22} Routine angiography/Doppler evaluation of the cervical vasculature is often unnecessary, but it should be considered in cases with multiple prior procedures, a history of severe vascular disease, multiple vascular/surgical insults, or chronic wounds.²³⁻²⁵ Regarding the radial forearm flap, preoperative imaging of the palmar arch is frequently not indicated, but a negative Allen's testing does not preclude significant vascular disease of the palmar arch, and preoperative Doppler imaging may be considered if significant vasculopathy is suspected.^{23,24,26}

Reconstructive Implications for Vessel Orientation

There are several objectives that should be recognized by the microsurgeon for successful pedicle orientation. The most obvious are related to vascular compromise of the flap. The experienced microsurgeon makes every effort to recognize the potential factors leading to vascular compromise prior to performing microvascular anastomosis. Repositioning transferred tissues and the vascular pedicle is infinitely more

difficult, if not impossible, if the possibility of compromise is recognized after the flap inset and microvascular anastomosis has been performed. Avoiding vascular pedicle compression related to anatomic factors, flap orientation, and skin closure is relatively obvious but can be difficult to achieve if the potential for compression is not recognized early during reconstruction. Similarly, it is important to avoid a kink or twist in the vascular pedicle during flap positioning. Favorable pedicle geometry implies gentle

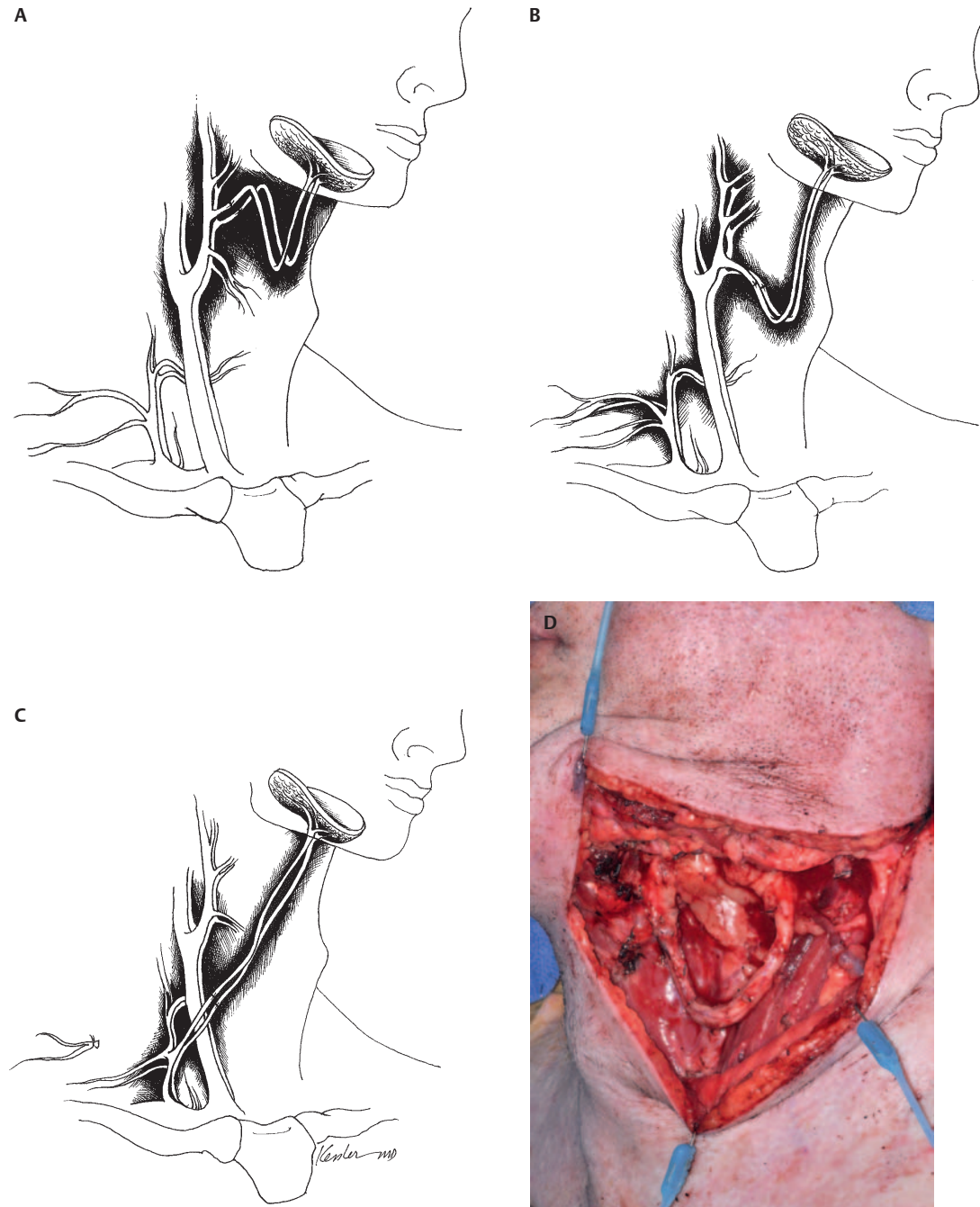


Fig. 10.2 Vessel geometry is exceptionally important. If there is excessive redundancy of the vascular pedicle, there is an increased risk of kinking and thrombosis. **(A)** The least desirable situation, with two vascular kink points. **(B)** A moderate risk, with one vascular kink point. **(C)** The optimal geometry, with no kink points. The length of the vascular pedicle determines the optimal donor-recipient relationship. **(D)** A clinical example of a gentle vessel curvature that helps prevent kinking.

pedicle curvature with alignment of the microvascular anastomosis (**Fig. 10.2**). Although external cutaneous monitors may be helpful in select cases, flap orientation complexity increases with their use and may compromise the geometry of the reconstruction.

Perhaps less obvious is the avoidance of placing the microvascular anastomosis in positions of possible peril. These positions include pedicle placement adjacent to areas of

possible pharyngeal anastomotic leak, tracheostomy sites, positions of external compression leading to vascular compromise, and positions immediately beneath areas of cutaneous vascular compromise, which may lead to anastomotic exposure (**Fig. 10.3**).

Planning for double free tissue transfers requires further attention by the microsurgeon to avoid technical difficulties related to pedicle geometry and vessel availability. Avoiding

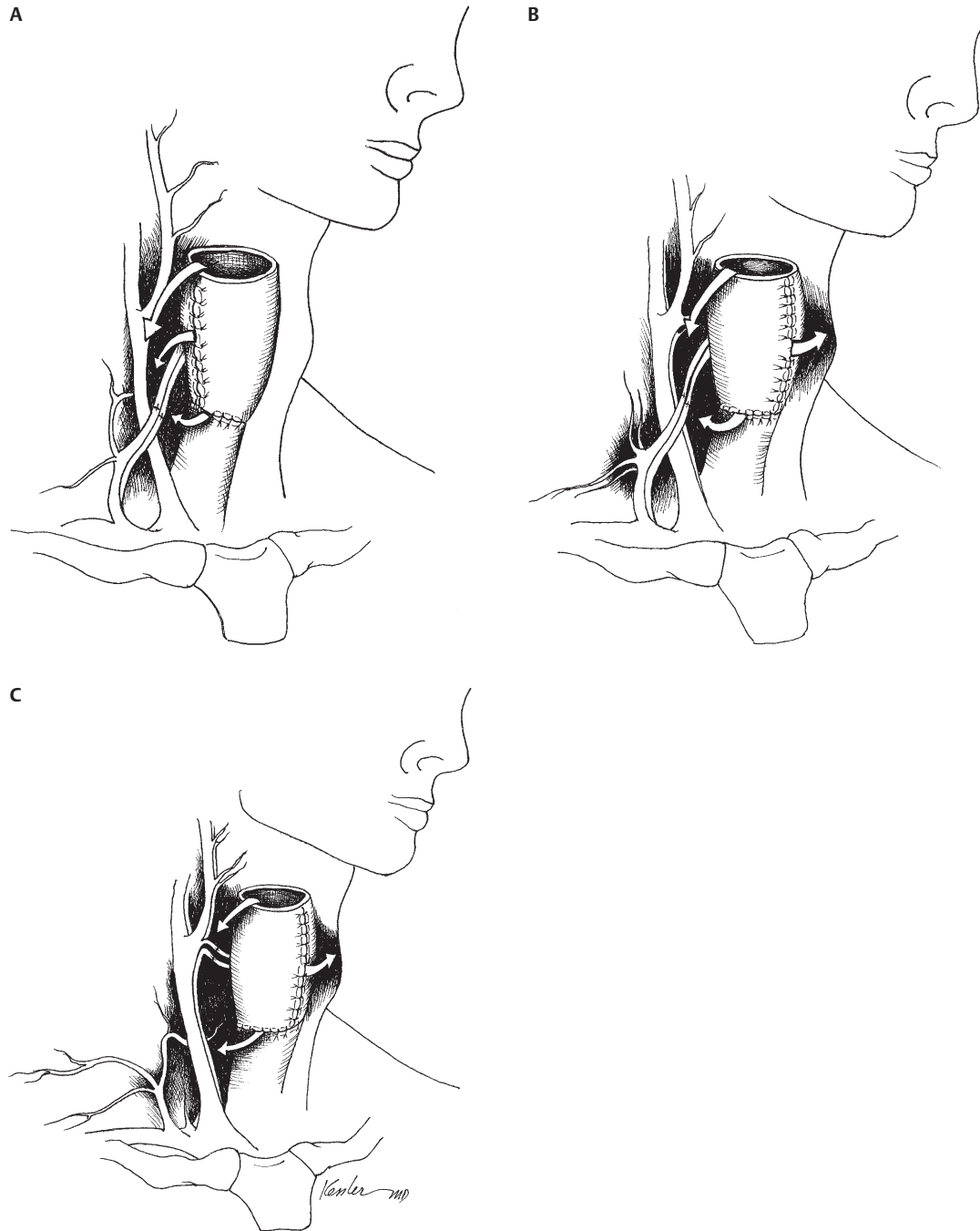


Fig. 10.3 The position of the vascular anastomosis relative to the oral or pharyngeal suture line should be considered. In the event of an oral or pharyngeal fistula, salivary contamination can be minimized if the vascular anastomosis is situated away from the pharyngeal suture lines (**A**). (**A**) The vascular anastomosis is exposed to one superior suture line. (**B**) The orientation of the vascular anastomosis is exposed to two suture lines. (**C**) This is the least desirable orientation, exposing the vascular anastomosis to three suture lines.

unnecessary destruction of recipient vessels during tumor ablations is critical for successful reconstruction in these situations. Pedicle length and diameter match with proposed recipient sites should be planned prior to flap inset. Pedicle orientation issues, which remain unrecognized until the second tissue transfer is prepared for anastomosis, are problematic and may be avoided with appropriate planning. It should be noted that the previously radiated or operated neck does not preclude the use of recipient vessels from that side. Additionally, sequential or “piggyback” configurations should be avoided, as proximal anastomotic compromise may sacrifice both reconstructions.^{27,28} Similarly, configurations resulting in retrograde flow, although possible in the first vascular territory, are not generally recommended due to decreased vascularity and flap survival. Although this finding may seem intuitively obvious, many authors have reported retrograde anastomosis despite the evidence of the inherent risks associated with this technique.²⁹

Surgical Technique and Considerations

- ◆ The primary goal of pedicle orientation is to avoid vascular compression and vessel kinking that results in vascular compromise; this goal take precedence over all other considerations.
- ◆ Careful attention to small cutaneous perforators is required to avoid compromise; harvesting small perforators with a muscle cuff is recommended if possible.
- ◆ Prior to performing microsurgical anastomosis, the microsurgeon verifies the position of the reconstructive tissue to optimize pedicle orientation and geometry.
- ◆ The order of microvascular anastomosis (arterial versus venous) may vary depending on the pedicle geometry to facilitate microsurgery.
- ◆ Avoid placing the anastomosis in positions of peril.
- ◆ Microvascular anastomosis should be performed to the highest flow vessels available that do not compromise pedicle geometry.
- ◆ Careful planning for double free tissue transfers will avoid unnecessary technical difficulties during microsurgery.
- ◆ The external cutaneous paddle for monitoring should not be employed at the expense of appropriate pedicle geometry.
- ◆ Avoid retrograde flow configurations if possible.

Vessel Preparation Prior to Anastomosis

The preparation of vessels prior to microsurgical anastomosis is a critical component of microsurgery, although it is often overlooked in the microsurgical literature. Preparation of both the recipient and donor artery should provide adequate vessel length for anastomosis without damaging the vessels. Careful attention to avoiding manipulation of the internal lumen and vessel intima to prevent damage to the endothelium is paramount to prevent arterial thrombosis.

Recipient/donor veins are similarly prepared, although careful examination of the internal anatomy is required to avoid adjacent branches or valves, which may dispose the anastomosis to thrombosis. Careful vessel preparation improves visualization of the internal lumen of the vessels and allows the microsurgeon to prevent vessel wall overlap during anastomosis. Adventitia may interfere with knot tying and, of greater concern, be trapped within the lumen of the anastomosis in situations of inadequate vessel preparation. Additional vessel preparation may be required in special circumstances such as vein grafting, application of monitoring devices, or for certain vessel configurations.

Surgical Technique and Considerations

- ◆ Microscopic/loupe visualization is critical; avoid vessel preparation/manipulation without magnification.
- ◆ Prepare the vessels adequately for anastomosis, and avoid aggressive vessel manipulation and manipulation of the internal lumen.
- ◆ Prepare sufficient vessel length to avoid adventitial interference and provide sufficient nontraumatized vessel length to facilitate microsurgery.
- ◆ Radiated/thickened vessels may require additional preparation to provide optimal vessel wall thickness for accurate anastomosis.
- ◆ Heparinized saline (100 U/mL) is used for irrigation and visualization and prevention of thrombosis during microsurgery.

MICROVASCULAR ANASTOMOSIS

Arterial Anastomosis

In many centers, microvascular anastomotic technique remains relatively unchanged, with microvascular anastomosis generally being performed with traditional suture techniques utilizing microsurgical monofilament. Suture materials most often utilized for microsurgery include non-absorbable monofilament such as nylon or polypropylene. This size of the selected material varies depending on the application; however, 8.0, 9.0, and 10.0 diameter sutures are adequate for the majority of microvascular applications in the head and neck. As the diameter of the suture material increases, so does the stiffness, and the microsurgeon should be aware that larger diameters may require additional attention to knot setting and orientation to prevent poor vessel approximation and open knots. Smaller suture diameters (<10.0) are more flexible but are more prone to breakage and may not have sufficient rigidity for optimal manipulation characteristics when the surgeon is tying knots. Needle selection includes tapered, spatula, and sharp point/cutting designs. In general, tapered microsurgical needles are sufficient for most applications, but many microsurgeons prefer sharp point or cutting spatula designs for ease of vessel penetration. These sharper designs may be especially helpful if significant atherosclerosis or medial wall thickening is

present. Ultimately, the selection of suture material and the associated needle is up to the microsurgeon and will become more consistent with experience.

Although end-to-end vessel anastomosis of appropriately size-matched vessels is considered optimal, several configurations are acceptable, provided that appropriate microsurgical principles are observed. Investigations comparing end-to-end and end-to-side arterial anastomosis have demonstrated equivalent vessel patency, blood inflow, and area of flap survival.^{29–32}

Surgical Technique and Considerations

- ◆ Simple, interrupted, full-thickness sutures represent the standard technique.
- ◆ Multiple variations of suture techniques may be successful with adherence to the principles of microsurgery.
- ◆ End-to-end vessel anastomosis of appropriately size-matched vessels is considered optimal.
- ◆ End-to-end anastomosis is equivalent to end-to-side anastomosis in terms of patency.
- ◆ Avoid vessel tension, if present vein grafting is preferred.

Modifications of suturing technique are also extremely helpful for microvascular anastomosis especially in situations of small or thin-walled vessels. Use of Acland suture loops and the “insert sutures first, tie later” and “loops on hanger” techniques offer solutions for lumen visualization during small vessel microsurgery.^{33,34} Adjunctive armamentarium, including vessel clamp frames, microsurgical background, and cellulose sponge spears, is used at the discretion of the microsurgeon to facilitate anastomosis. Often with larger, easily visualized vessels microsurgical frames and background are unnecessary and may actually impair suture placement increasing the risk of suture tangle or breakage. Conversely, approximation clamps and microsurgical background may be extremely helpful if not required for the approximation of extremely small vessels or in situations in which vessel geometry prohibits the ideal positioning of the vessel ends for anastomosis.

At the conclusion of microvascular vessel approximation, careful examination of the anastomosis is performed. Obvious, high-flow leaks should be repaired immediately; however, a small amount of leakage of the arterial anastomosis is commonly observed and will resolve in a short period of observation. Once vascular flow is verified, the vascular pedicle and anastomotic sites are bathed with warm irrigation. Topical vasodilators such as papaverine, calcium channel blockers, and local anesthetics are commonly used by microsurgeons, but the scientific evidence for their use is limited.³⁵ Although vascular spasm is commonly observed and will slowly resolve with observation, complete lack of arterial flow requires takedown and investigation of the anastomosis. Often, sharp excision of the arterial anastomosis with repeat anastomosis is required, and attempts to remove a few sutures and examine the anastomosis or irrigation to restore patency are not recommended.

Vessel Mismatch (Figs. 10.4 and 10.5)

Often the microsurgeon encounters a situation of vessel diameter mismatch when performing microvascular anastomosis. Meticulous microsurgical technique with careful attention to suture spacing during placement often resolves the majority of these situations. Multiple adjuvant techniques exist to facilitate vessel approximation during these situations. The open-Y technique used at vessel bifurcations may allow for improved vessel diameter match.^{36,37} Angled or “fish mouth” arteriotomy may also allow the microsurgeon to achieve adequate vessel diameter for anastomosis.³⁸ Interposition vein grafting has been evaluated but may result in altered flow mechanics at the anastomosis, depending on the technique utilized.^{39,40} Application of ligature clips to decrease lumen diameter in veins has been reported.⁴¹

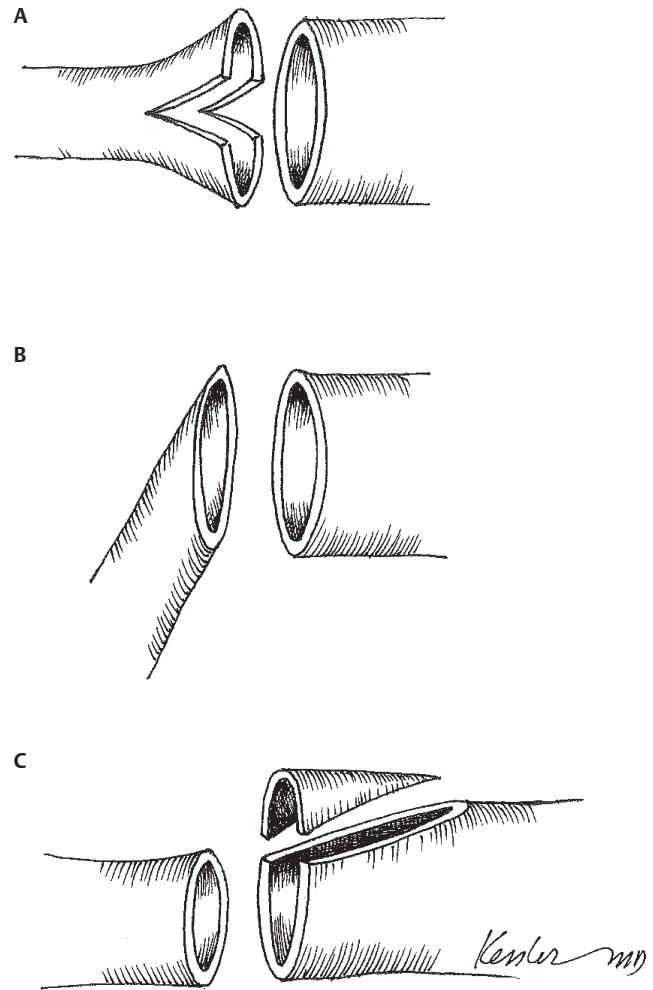


Fig. 10.4 These approaches represent three options to manage a vessel size mismatch. **(A)** A “fish mouth” approach. **(B)** This approach requires a beveled cut along the vessel to increase the lumen size. **(C)** A tapering technique that reduces the vessel lumen to provide a anastomotic match.

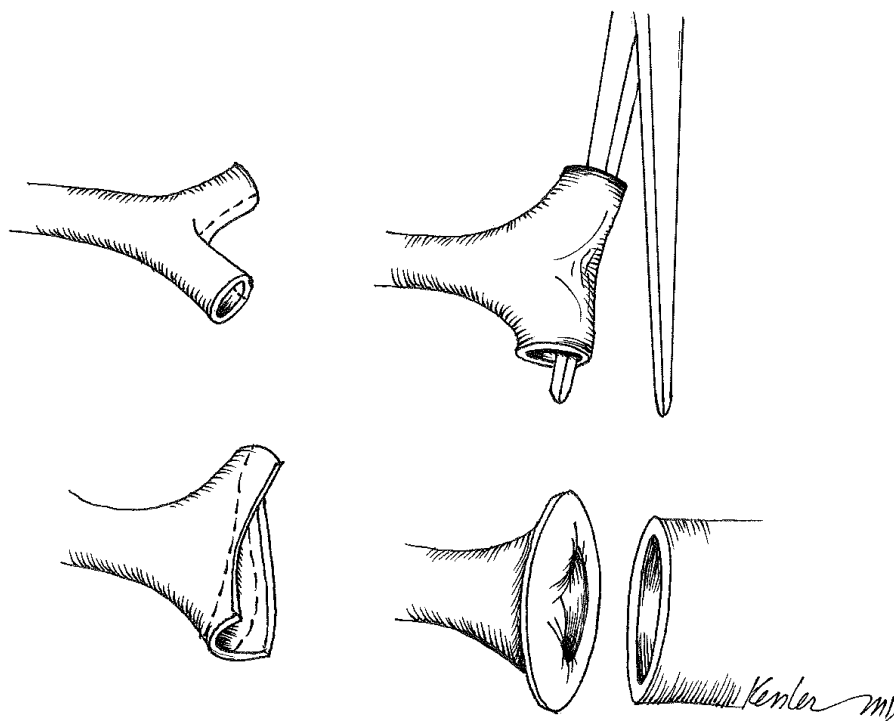


Fig. 10.5 The open-Y technique used at vessel bifurcations may allow for improved vessel diameter match.

Adjuvant Techniques

The current literature demonstrates that adjuvant techniques such as application of the anastomotic coupler, fibrin glue, or laser-assisted welding of anastomoses are currently being explored.^{32,42} Laser welding of the arterial anastomosis has been attempted to reduce the number of microsutures required, but it was not reliable for larger vessels with increased luminal pressure.³² The anastomotic coupling device has been used with some success with arterial anastomosis as well, and is ideal in larger diameter arteries with sufficient wall flexibility for application of the device.^{38,43,44} Novel nitinol arterial suturing clips developed for cardiovascular surgery, which avoid microsurgical knot tying, have also been explored to decrease microvascular anastomosis time and prevent thrombosis.⁴⁵ Clearly, technological advances continue to be applied to microvascular anastomotic technique, and these advances will likely contribute to more efficient and effective microvascular anastomosis without compromising reliability, rate of thrombosis, and overall success of free tissue transfer in reconstructive procedures.

Venous Anastomosis

Microsurgical venous anastomosis has several distinct differences when compared with arterial anastomosis. Although the principles of vessel manipulation and microsurgical techniques are relatively constant, small veins are distinctly prone to twisting and kinking.⁴⁶ Additionally, venous valves are present and may impair microsurgical anastomosis or predispose to thrombosis if they are unrecognized and

removed. In situations of valves near the junction of the proposed donor vein and internal jugular vein, it is often prudent to perform end-to-side jugular anastomosis rather than risk valve interference. These differences become even more important when one considers the fact that venous anastomotic failure leading to venous congestion is the primary reason for microvascular free tissue transfer failure. In terms of vessel orientation, end-to-end and end-to-side configurations have been formally evaluated, and no difference in flap failure due to the configuration was elucidated.⁴⁷ The primary goal of venous geometry is to prevent kinking of the vessels and provide adequate venous outflow after the anastomosis is performed.

There have been several investigations attempting to determine if double venous anastomoses offer an advantage over single venous anastomoses. Large retrospective investigations have demonstrated a small advantage in terms of flap success rates when two venous anastomoses are used.⁴⁸ Some authors have suggested that a second venous system (i.e., internal and external jugular systems) should be used if possible.⁴⁹ The intuitive advantages of double venous anastomoses such as improved venous drainage and insurance in the event of thrombosis of one of the venous anastomoses may offer an advantage, but this has not been proven scientifically. In contrast, an investigation related to microvascular blood velocity determined that peak velocity decreased as the number of venous anastomoses increased, which confirms the physical laws of fluid mechanics.⁵⁰ This may indicate that two venous anastomoses result in slower flow in the venous system when compared with a single venous anastomosis and may predispose the flap to venous thrombosis. Nevertheless, review of the microsurgical literature reveals that routine use of double venous anastomoses is

unnecessary but may be advantageous in situations when the microsurgeon wishes to access separate venous outflow systems.

At the conclusion of microvascular anastomosis, venous outflow should be confirmed by performing a vascular strip test by occluding the vessel distal to the anastomosis with a microforceps and stripping the vessel with another microforceps proximally across the anastomosis. Release of the proximal forceps should demonstrate brisk venous fill of the vessel.

Surgical Technique and Considerations

- ◆ The primary goal of venous geometry is to prevent kinking of the vessels and provide adequate venous outflow.
- ◆ Venous anastomoses are more prone to kinking and twisting than are arterial anastomoses.
- ◆ End-to-end and end-to-side anastomoses have similar patency and success rates.
- ◆ Venous valves should be sharply excised when adjacent to the proposed venous anastomoses.
- ◆ One quality venous anastomosis is sufficient, and it is unclear whether double venous outflow anastomoses offer an advantage over a single venous anastomosis.
- ◆ The internal jugular vein and its branches may be more favorable than other recipient veins, but the external jugular vein is a reliable alternative.
- ◆ Venous outflow is confirmed by performing the vascular strip test.
- ◆ Patency rates are equivalent when using the venous coupling device compared with hand-sewn venous anastomoses.

The use of the venous anastomotic coupling device has revolutionized venous anastomosis to some extent and allows for rapid, reliable venous coupling. Equivocal patency rates using the device have been shown when compared with traditional suturing techniques, and some authors have indicated the possibility of improved patency rates.^{44,51,52} Significant reductions in operative time have been realized when using this device without compromising outcomes.⁵² In addition, the coupling device may help to stent difficult veins and prevent compression at the anastomosis site (**Fig. 10.6**). Nevertheless, the principles of microsurgery must be observed, and careful attention during placement of the device is required to prevent twisting, bunching, or intimal damage. As the diameter of the vein decreases, the difficulty of applying the coupling device increases as the working space for manipulation over the ring pins is smaller. Cellulose spears or specialized forceps may facilitate placing the wall of the vein over the ring pins while avoiding damage to the vessel. The coupler can be reliably applied in end-to-side anastomoses as well.

Systemic Anticoagulation

Systemic anticoagulation is routinely employed by microsurgeons to reduce thrombotic complications after

microvascular free tissue transfer.⁵³ Aspirin, heparin, dextran, ketorolac, and other agents are commonly employed to prevent thrombosis in the early postoperative period. A comprehensive discussion regarding systemic anticoagulation for free tissue transfer is beyond the scope of this chapter, but some general considerations should be mentioned. Although the majority of microvascular surgeons use some form of postoperative anticoagulation, there currently exists little consensus in the scientific literature regarding the optimal systemic anticoagulation protocol.^{53,54} Additionally, controversy exists about the effectiveness of anticoagulation agents in preventing flap compromise.^{55–57} Therefore, the benefits of anticoagulation regimens should be weighed against the risk of postoperative bleeding complications on an individual basis.⁵⁸ Many patients undergoing head and neck reconstruction require systemic antiplatelet therapy or subcutaneous heparin for other indications, making the decision straightforward. Systemic anticoagulation is generally continued until microvascular endothelialization of the lumen, approximately 4 to 7 days. It should be noted that arterial and venous blood velocities increase for the first 3 postoperative days, which likely explains the declining risk for pedicle thrombosis during this time.⁵⁹

The Vessel-Depleted Neck

The technical challenges of dealing with the vessel-depleted neck are widely recognized by microsurgeons and have resulted in a significant amount of literature related to the subject. Although radiation and chemoradiation definitely increase the difficulty of locating adequate recipient vessels, prior surgery is the most common reason for vessel depletion. As noted earlier in this chapter, a thorough review of the previous operative reports is important for surgical planning. Multiple strategies have been developed by microsurgeons who perform reconstruction in the vessel-depleted situation. These include transverse cervical vessels, internal mammary vessels, the cephalic vein/thoracoacromial system, and flow-through techniques of additional free tissue transfers.^{60–62} Arterial anastomosis has even been performed using the internal carotid artery and an internal carotid bypass shunt, although this technique has obvious inherent risks and is not widely accepted.⁶³ The appropriate selection of flaps with adequate vascular pedicles cannot be overstated, especially in maxillary/superiorly positioned reconstructions.⁶⁴

Thyrocervical Trunk

Perhaps the most widely utilized vascular system in the vessel-depleted situation is the thyrocervical trunk, which includes the inferior thyroid, superficial cervical, and suprascapular arteries.⁶⁵ As noted previously the vessels are found within the cervical fat overlying the anterior scalene muscle. The diameter and length are usually adequate for microvascular anastomosis. In addition this region is often less affected by previous therapy when compared with the external carotid system.



Fig. 10.6 Reconstruction of a pharyngocutaneous fistula in a patient with a vessel depleted neck who has been treated with multiple free flap surgeries. **(A)** The defect. **(B)** The preparation of the fistula for flap reconstruction. **(C)** The internal mammary vessels exposed after removing the medial aspect of the third rib. **(D)** The rectus abdominis flap and vascular anastomosis. **(E)** The final closure.

Internal Mammary (Fig. 10.6)

The internal mammary artery and vein are commonly employed by microvascular surgeons for free tissue breast reconstructions.^{66–68} Multiple investigations have shown this system to be reliable for microvascular reconstruction, and many studies have reported the internal mammary as an option in the vessel depleted neck.^{60,62,65,69} Access to the internal mammary artery has been described and generally requires dissection and removal of a segment of the medial aspect of the third rib.⁶² Subperichondrial dissection, followed by excising a small window of perichondrium, exposes the vessels. The pedicle (2–3 cm) may be lengthened by removing a portion of the second rib and transposing the vessels superiorly after distal ligation. Careful dissection is crucial to prevent inadvertently entering the pleural space,

which lies just deep to the vascular pedicle in this location. Approximately 12% of cases using the internal mammary system may require conversion to another recipient site due to vein reliability.⁶⁸ As in most vessel-depleted situations, selection of donor sites with long vascular pedicles facilitates anastomosis without resorting to interposition vein grafts.⁶²

It should be pointed out that exposure of the internal mammary system may be performed with a rib preservation technique. This technique was developed to avoid visible medial chest wall defects related to rib resection in breast reconstruction patients.⁶⁷ This technique is generally applied to breast reconstruction and may not expose adequate length vessels for head and neck reconstruction depending on the situation. Nevertheless, the rib preservation technique may be performed at higher rib interspaces resulting in superior vessel exposure and greater vessel diameter.⁶⁶



Fig. 10.7 The exposure of the cephalic vein for venous drainage in the vessel depleted neck.

Cephalic Artery/Vein (Fig. 10.7)

In cases where all cervical vessels are inadequate and the internal mammary system is in question (e.g., previous thoracotomy or chest reconstruction), the cephalic system may be utilized.⁷⁰ It has been used in a “wrist carrier” fashion for the severely depleted system in a delayed manner as well.⁷¹ The cephalic vein also may be used as a separate drainage system in vessel-depleted situations.⁷²

Vein Grafting

Situations with inadequate vessel length or quality may require vein grafting to facilitate microvascular anastomosis. There are multiple acceptable grafting sites such as the cephalic and the saphenous veins, and the forearm. Harvesting an additional vascular pedicle to serve as both arterial and venous grafts has also been reported to be successful.⁷³ In the event that a single vein graft will be used for both arterial and venous grafting, orientation of the vein graft is critical to avoid valve interference. This requires the graft to be reversed on the venous side relative to the arterial side. Another technique for dealing with this situation is the Corlett loop, which is a temporary arteriovenous (AV) fistula, which is subsequently sectioned and anastomosed to the free tissue pedicle.⁷⁴ In general, when vein grafting is considered, high-flow arteries are desirable, and once the decision to vein graft is made, accepting inadequate arterial inflow is ill advised. Therefore, arteries should be trimmed to adequate diameter for sufficient flow or an alternate artery selected if the initial planned vessel is questionable.

Surgical Technique and Considerations

- ◆ Vein grafting has been associated with increased rates of thrombosis.
- ◆ Harvest sites for donor veins should lie outside of previously radiated tissue.
- ◆ Vein orientation should be maintained during harvest prior to microvascular anastomosis to avoid valve interference with vessel flow.
- ◆ Vein grafting is favorable over excessive tension of the vascular pedicle.

◆ CONCLUSION

Vessel geometry and vessel selection can determine the success and failure rates of a reconstructive surgeon. Limiting risk by considering the favorable geometry, using high-flow vessels, and minimizing exposure to potential salivary leak sites are important concepts that should be considered in every case.

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